MODERN HOUSE CONSTRUCTION

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No. 1.

No. 2.

No. 3.

1. HALL, "ASHWOOD", BYFLEET, SURREY. 2, 3. DRESSING-ROOM AND MORNING-ROOM, "SURREY HOLME", BYFLEET.

The Principles & Practice of MODERN HOUSE CONSTRUCTION

INCLUDING PLAN AND DESIGN : CONSTRUCTION : WATER-SUPPLY AND FITTINGS : SANITARY FITTINGS & PLUMBING : DRAINAGE & SEWAGE-DISPOSAL : WARMING : VENTILATION : LIGHTING : STABLES & COW-HOUSES : SANITARY LAW : &c.

BY MANY LEADING SPECIALISTS
UNDER THE EDITORSHIP OF

G. Lister Sutcliffe

ASSOCIATE OF THE ROYAL INSTITUTE OF BRITISH ARCHITECTS
MEMBER OF THE ROYAL SANITARY INSTITUTE

NEW EDITION

Thoroughly revised and considerably extended

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SECTION VIII.

SEWAGE-DISPOSAL

BY

H. PERCY BOULNOIS

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SECTION VIII.—SEWAGE-DISPOSAL.

CHAPTER I.

SEWAGE.

An important consideration, so far as a sanitary house is concerned, is the getting rid of the waste products known as "sewage", in a manner that shall be expeditious, inoffensive, and economical. The question of sanitary appliances, drains, and traps has been dealt with by other contributors, but the question of the ultimate disposal of the sewage must now be considered.

In nearly every town or large community in the United Kingdom, the sewage from the houses now passes by underground conduits or drains direct into the arterial system of sewers, to be ultimately dealt with in a variety of ways which will be presently described. The disposal of the sewage from isolated or country houses is a more difficult problem, which in its turn will also be discussed. Before proceeding to deal with the question of the disposal of sewage from towns, it will be well to consider its composition and quantity.

Sewage may be described as the various waste products from communities, mixed with a quantity of water which varies with the supply, and the admittance or otherwise of the subsoil and rain water, and also the habits of the community. The measure of the dry-weather flow may be readily estimated, when the supply of water per head of the population is ascertained, but allowance must be made for subsoil water in those cases where it is admitted, either purposely or accidentally, into the drains and sewers. In addition to which must be added the "manufacturers' waste", which in some special cases is necessarily considerable. The storm-water flow, which is dependent upon the rainfall, is, on the other hand, somewhat difficult to estimate, without a series of observations extending over a considerable period of time, and made with a view to estimate the amount of the rainfall upon the area drained by the sewers; and provision must be made for dealing in some manner with the *maximum* quantity of water which is likely to reach these sewers.

With regard to the chemical composition and degree of dilution of any sewage, this must also necessarily vary in every district, but the late well-known chemist, Dr. C. Meymott Tidy, made the following determination of the **excrementitious matter in sewage:—**

"Every adult male person voids on an average 60 ozs. (=3 pints) of urine daily. The 60 ozs. contains an average of 2·53 ozs. of dry solid matter, consisting of—

Urea, ...	512·4 grains.
Extractives (pigment, mucus, uric acid), ...	169·5 „
Salts (chiefly chlorides of sodium and potassium), ...	425·0 „
	1106·9 = 2·53 ozs.

"Every adult male person voids about 1750 grains (or 4 ozs.) of fæces daily, of which 75 per cent is moisture. The dry fæcal matter passed daily is therefore about 1 oz. per adult head of the population. Of this dry fæcal matter, about 88 per cent is organic matter (of which 6 parts are nitrogen), and 12 per cent inorganic (of which 4 parts are phosphoric acid); of this dry fæcal matter, 11 per cent is soluble in water."

Other experimentalists give about 36 ozs. of urine and $1\frac{1}{2}$ ozs. of fæcal matter for each person in 24 hours, and Messrs. Wolff & Lehmann, from investigations made with a mixed population of 100,000 persons for a year, give the following result:—3 ozs. of fæcal matter and 26 ozs. of urine per day. It will thus be seen that there is some divergence of opinion as to the average amount of these matters voided daily by an adult, and it is really more important for our purpose to ascertain what is the composition of water-carried sewage. This was determined by the Rivers Pollution Commissioners in their first report as follows:—

Table XXV.

DISSOLVED AND SUSPENDED MATTER IN SEWAGE.

IN PARTS PER 100,000.

Description.	Matter in Solution.	Suspended Matter.			Total in Solution and Suspension.
	Total Solids.	Mineral.	Organic.	Total.	
Water-closet Towns, -	72·2	24·18	20·51	44·69	116·89
Midden Towns, - -	82·4	17·81	21·30	39·11	121·51

This shows that there is as a rule only ·116 per cent of solid matters, in solution and suspension, in water-carried sewage in this country. It must not, however, be forgotten that this solid matter is of an extremely putrescible character, and hence the danger of untreated sewage, especially in cases where there may be in addition large numbers of dangerous pathogenic bacteria, or disease-germs. The

problem is to remove from the sewage and render innocuous the whole of this decomposable organic matter (small though it is in proportion to the large volume of water in which it is carried), and also to destroy the dangerous germs which are carried in it, and which, if allowed to mix with the air we breathe or the water we drink, become so dangerous to our health and lives.

Up to the present date the following may be taken as **the various methods of sewage-disposal** which have been tried:—

(1) *Outfalls into the sea, estuaries, or large rivers*: in other words, disposal by dilution.

(2) *Treatment of the sewage with various chemicals in tanks or otherwise*: in other words, disposal by antiseptic treatment or precipitation.

(3) *Filtration through artificial filters* of various kinds, or through land: in other words, disposal by mechanical separation of the solids, and by nitrification.

(4) *Broad irrigation*: in other words, using the sewage for manurial purposes on land, and at the same time purifying it by filtration and nitrification.

(5) *Septic or natural decomposition*: in other words, allowing natural decomposition to act on sewage and to break up and destroy the solids, and allowing nitrification to purify the effluent. This treatment is gradually superseding chemical treatment.

CHAPTER II.

OUTFALLS INTO THE SEA, ESTUARIES, AND LARGE RIVERS.

Under certain circumstances and with proper precautions, **the discharge of crude sewage into the sea** can be carried out in a satisfactory manner without danger of any nuisance, and such a disposal has much to recommend it. All towns situated on our coasts deal with their sewage in this manner, and it is only where the outfalls have been badly selected that any evils result. There are many scientists who contend that this is a wasteful practice, and that the valuable manure contained in sewage should be returned to the land from whence it originally came in the form of food; but hitherto it has been found that, owing to the enormous dilution by water of the more valuable manurial products in sewage, it is more economical to dispose of sewage in the most rapid and sanitary manner and deal with the land in other ways.

The essential points to be considered in dealing with this method of sewage-disposal may be briefly stated. The outfall must be carried well below the low-water mark of the lowest known tide; otherwise a nuisance is very likely to be caused. It must also be carried to such a point that the incoming tide or wind will not bring the sewage back upon the shore, and that the sweep of any currents in the locality will not have the same effect upon adjacent coasts.

In order to obviate such a possibility, and also to ensure that the point of outlet is so selected that the sewage will always, under all conditions of winds and tides, be carried well away to sea and not coast along any neighbouring shores, **very careful and complete float-observations** must be carried out under all possible conditions of wind and tide. These observations must not only be made with surface-floats, but also with submerged floats at different levels, and the various tracks or courses which these floats take must be followed and marked upon proper charts. When the most suitable spot has been thus determined, it may be found that even then it will not be safe to allow the sewage to flow continuously, but that it must be stored in tanks and only allowed to flow at some particular level of the ebb-tide. It is almost unnecessary to add that the culvert conveying the sewage to the submerged point of outlet must cause no obstruction to the navigation along the shore, and that it must be so marked with buoys or "perches", or be so visible both by night as well as day if necessary, that no accident to boats or shipping will occur.

It is no part of this article to enter into any details of engineering construction, but it may be well to give the following description of **the outfall works at Portsmouth,** as they afford an excellent example of a well-designed and carefully-constructed sea-outfall, carried out under the conditions which have been enumerated. The daily dry-weather flow of the sewage of Portsmouth was about 4,500,000 gallons when these works were carried out. The surrounding district is very flat, and for some miles the land only reaches a height of a few feet above the high-water mark of spring-tides. The sewage therefore has to be pumped. The Isle of Wight is opposite, and there is no promontory along the coast near to Portsmouth which could be selected for a suitable outfall. A reference to the plan (fig. 424), however, will show that there is a large land-locked harbour, called Langstone, situated about two miles to the east of Portsmouth, which at high water is filled with an enormous volume of water, and this water, as the tide falls, rushes through the narrow channel communicating with the sea; this narrow channel naturally suggested itself as a suitable locality for the outfall. Numerous and extended float-observations confirmed this opinion, as it was found that floats of all descriptions were without exception carried well away

to sea, if placed at this point *about one hour after the flood-tide had turned.* The plan clearly shows the value of these float-observations, as not only was a

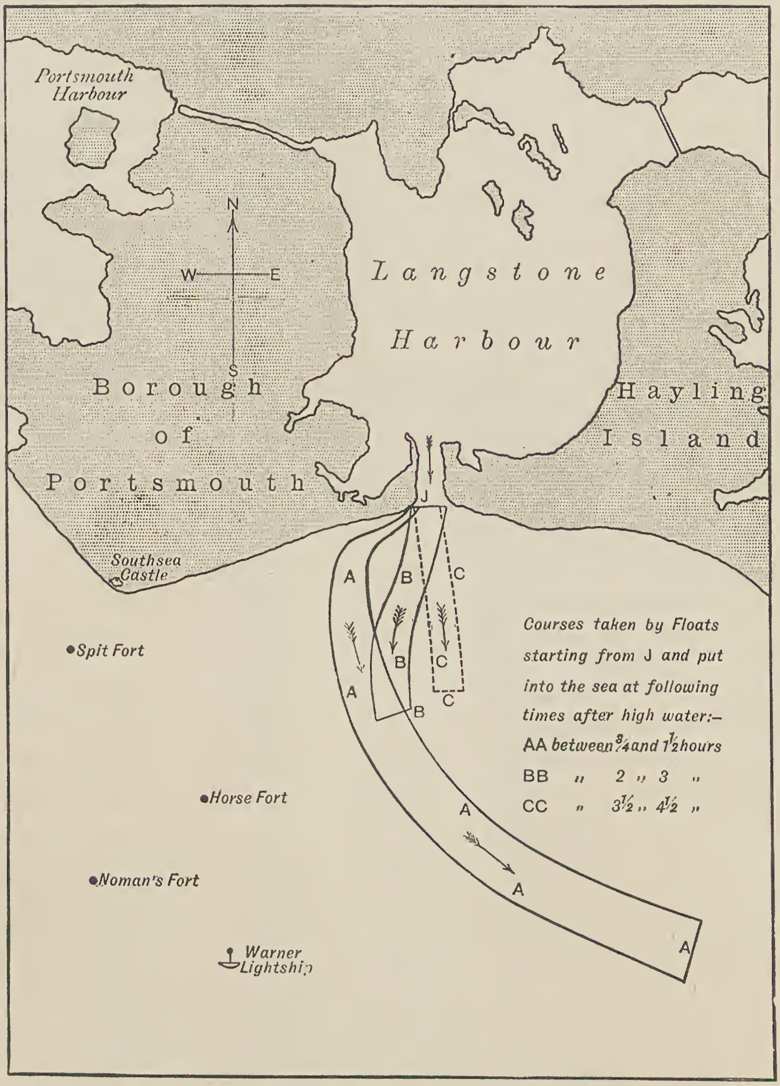

Fig. 424.—Borough of Portsmouth: Sewage-outfall Works. Plan showing float-observations taken from the outfall.

most suitable position for the outfall determined, but also the most suitable times of tide for releasing the sewage were also ascertained.

The sewage is raised at a pumping-station about a mile from the outfall, and forced along iron rising-mains to tanks close to the point of outfall. There are three of these tanks placed side by side, with a collective capacity of 4,500,000 gallons, and covering an area of $3\frac{1}{4}$ acres. Each tank is 160 feet in length and 150 feet in breadth, constructed of cement-concrete. They are arched over and

covered with soil and grass. The inverts are segmental in cross section, with a longitudinal fall of 1 in 150 to the outlets. In order to allow the whole of the contents to be discharged within about an hour and a half of high water, the level of the inverts has been placed one foot below ordinary high-water mark.

The quick discharge of the contents of these tanks is a special feature of the scheme, as it has to be accomplished in about three-quarters of an hour. The tanks first discharge into a culvert, seven feet by six in size, from which three lines of cast-iron pipes three feet six inches in diameter are carried well into the tide-way, their mouths being just below low-water mark.

The arrangement by which the large penstocks, which let the sewage from the tanks to the culvert, are opened, is very ingenious. At the moment when the discharge ought to take place, a man opens a small penstock from the top of the tank, the escaping sewage from which operates a turbine, which sets in motion the machinery by which the large and heavy penstocks are opened, thus liberating the sewage in large volume, and with a very small expenditure of time and labour. These works and cutfall have been in successful operation for the past eight years, and no nuisance or trouble of any kind has been occasioned thereby. They were designed and carried out by the late Sir Frederick Bramwell and Mr. Graham Harris, and are the best example of a successful sea-outfall with which the author is acquainted.

An outfall into an estuary may also be successfully carried out, where the volume of water passing out to sea is very largely in excess of the quantity of sewage poured into it, and where from its velocity the sewage will be carried well past the shores and away to sea, and where no obstructive banks or bars will be formed by the detritus or heavier particles in the sewage settling on the bottom, and thus perhaps causing serious obstruction to navigation or impediment to the flow of water.

There are many instances of successful sewage-disposal into estuaries, the most notable being that of Liverpool, which pours nearly the whole of its sewage in a crude state into the river Mersey. The dry-weather flow of this sewage amounts to about 10 million gallons in twenty-four hours, but owing to the large volume of water entering the Mersey at each tide, and the quick velocity of the flow of the ebb-tide, no trouble has ever occurred during the great number of years this method of disposal has been practised. There are twelve outfalls of various sizes discharging their contents below low-water mark, and though the outfalls are in many cases close to the entrances of docks, no nuisance whatever has arisen.

Outfall into a river is to be deprecated except under very exceptional cir-

cumstances, such as when the river consists of a very large volume of water, and where the water below the outfall is not used for domestic purposes. Unfortunately, owing to the facilities and economy of thus disposing of sewage, it was almost universally the practice throughout this country when sewers first came into vogue, but the effects produced on the rivers, and even on the health of the inhabitants in their vicinity, were so disastrous that steps were very early taken to prevent or mitigate the nuisance thus caused, and the whole question as to the proper disposal of sewage thus began to be discussed. Unfortunately there are still many cases of river-pollution in this country by sewage and manufacturers' wastes, and the condition of many of the rivers and streams in this country is a disgrace to the Local Authorities who are responsible for their condition.

The Public Health Act (1848) did not deal with the question of **the pollution of rivers,** nor did the great Public Health Act (1875), as these acts were permissive rather than compulsory, and even the Rivers Pollution Prevention Act (1876) entirely failed in its object. The Local Government Act of 1888, which gives certain powers to County Councils to enforce the provisions of the Rivers Pollution Prevention Act, has, however, led to something being done to remedy the great evils at present existing. It is to be hoped that the Royal Commission on Sewage Disposal, which is now sitting, may be the means of clearing the tangle into which this question has drifted, and that efficient legislation may follow its conclusions when the final report is issued.

Fortunately for us, Nature herself provides her own self-cleansing powers, or we should all soon suffer from our negligent uncleanliness. The action of the oxygen of the air and in the water, the absorption of organic impurities by plants, and, above all, the myriads of bacteria to which the processes of putrefaction and nitrification are due, are constantly at work purifying our polluted rivers, and rendering them again fit for the use of man; but there can be no doubt that the practice of turning our waste products into rivers—and particularly small rivers and streams—is to be greatly deprecated, as numerous cases are on record where the germs of typhoid fever have been carried in rivers for long distances, and have led to outbreaks of the disease in places many miles away, where the water has been drunk. The only safe course is to adopt some method of purification on the lines hereafter laid down.

CHAPTER III.

TREATMENT OF SEWAGE WITH VARIOUS CHEMICALS.

The evils arising from the introduction of drains and sewers in place of the old middens and cess-pits, and the desire to prevent the waste of what was then considered to be a valuable manurial product, many years ago induced chemists and other scientific men to attempt to discover a universally satisfactory method of sewage-disposal. Many and various were the remedies suggested, and much time and a great deal of money were expended in the endeavour to find some method which would stop decomposition, and by the aid of chemicals remove or render harmless all the organic matter and dangerous organisms contained in sewage, arrest whatever was of manurial value, throw down all the matters in suspension, and at the same time allow the effluent water to escape in a wholesome condition. This was the problem, and up to the present time no thoroughly satisfactory solution has been found by which this can be effected by chemicals. It would be very interesting, did space permit, to recount the various systems of deodorization, antiseptic treatment, and precipitation, which sprang into existence and lived for longer or shorter periods, but this would not serve any very useful purpose, and the following short list and description will suffice.

1. **Sillars's "A.B.C. Process"** of dealing with sewage found considerable favour at one time, and derived its name from the ingredients which were used for the purpose of precipitating the solids and purifying the effluent of the sewage in tanks. These ingredients consisted of alum, blood, charcoal, clay, magnesia, and other compounds, some of which were afterwards found to be unnecessary. Although considerable purification of the sewage took place, the amount of sludge left in the tanks proved to be a stumbling-block, and the sale of this material was difficult. This process, with modifications, is still in use at the Sewage Disposal Works at Kingston-on-Thames, and it is claimed for it that less tank capacity is required, that the tank effluent is greatly purified, and that this effluent can consequently be more easily dealt with on land or by artificial filtration. The sludge produced by this treatment has considerable market value as a manure.

2. **Lime Treatment.**—There are still many Sewage Disposal Works where lime is added for purposes of precipitation in tanks, though this method is being in turn superseded by treatment with alumino-ferric. Only the purest lime should be used, and this must be thoroughly slaked before being added to the sewage. It is nearly always used in the form of milk of lime, the average dose

seldom exceeding 1 ton of lime to each million gallons of sewage treated. Thorough mixing of the lime and sewage is essential, and there are several methods for effecting this. There should also be sufficient tank capacity to ensure a proper deposition of the solid matters in suspension.

3. **Alumino-ferric,**[1] or sulphate of alumina and iron, is very usually employed

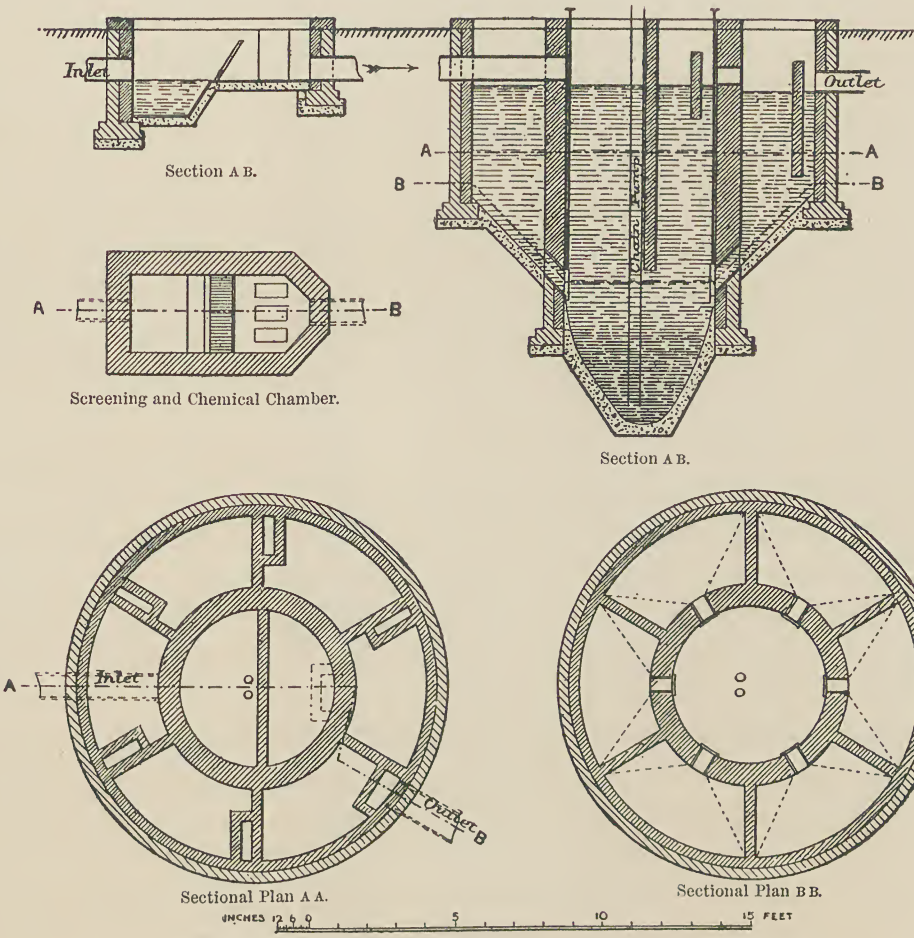

Fig. 425.—Cosham's Sewage-precipitation Tank, with Screening and Chemical Chamber.

where chemical treatment is resorted to, as it can be obtained in solid cakes, which can be placed in the channel carrying the crude sewage, where the cakes gradually dissolve, and thus the material is easily mixed in proper quantity with the sewage.

4. **The Amines Process** was introduced some years ago by Dr. Wollheim, and consisted in the addition of ordinary herring-brine to the lime. A soluble gas

[1] Alumino-ferric is said to be composed as follows:—Soluble alumina, 14·00 parts; peroxide of iron, ·75 part; sulphuric acid, 33·81 parts; water, 51·44 parts; total, 100·00 parts.

was said to be produced, which acted as a "germicide", but the process has not met with the success that was at one time anticipated.

5. **Cosham's System** claimed to effect a more perfect purification of the sewage by prolonging the period during which contact is maintained between the chemical introduced into the sewage (preferably alumino ferric) and the sewage. The special construction of tank required in this process is shown in fig. 425. The chambers in these tanks are said to arrest in a remarkable manner the albuminoids and flocculent matters in the sewage.

6. **The Hermite Process** consisted in the electrolysis of salt water by electric currents, thus producing chlorine, which was added to the sewage in the drains or sewers. It is claimed that the sewage thus treated arrived at the outfall in a perfectly inoffensive condition. It was also stated that the engine and dynamo power required to produce sufficient chlorine to purify about 1,500,000 gallons of sewage is only about 100 horse-power, working continuously for ten hours. There can be no doubt that under certain conditions, and to meet special cases, some such process has considerable merits.

The difficulties and objections to be met with in dealing with sewage by chemical processes may be summed up as follows:—

(1) The varying character of the sewage to be dealt with, not only in different towns but also almost hourly during each day, this being intensified where, as in most cases, the sewage contains trade refuse or wastes, which are often very refractory under the influence of the chemicals used for the treatment of the sewage.

(2) The tendency of all chemically-treated effluents to revert to decomposition, this having only been temporarily arrested by the treatment.

(3) The first cost of the necessary works and plant, and the subsequent expense of treatment.

(4) The disposal of the sludge which is precipitated to the bottom of the tanks.

CHAPTER IV.

THE DISPOSAL OF SEWAGE SLUDGE.

A residuum which is technically known as "sludge" remains, as already stated, in all sewage-settling tanks after chemical treatment, and the ultimate disposal of this offensive, slimy semi-fluid material is by no means an easy matter. The amount of sludge produced from a given quantity of sewage

is naturally very varied, according to the quality or consistency of the sewage and the description and amount of the chemicals used in the process. For instance, it appears that the amount of sludge produced daily at Birmingham from the sewage of a thousand persons is nearly a ton (a cubic yard of sludge weighs about 16 cwts.), whereas, for the same number of persons at Chiswick, the amount of sludge is about a ton and a half, and at Leeds only a third of a ton.

The manurial value of sludge in its crude state is negligible, owing to the excess of water it contains (about 95 per cent), but when dried it is said to be worth about as much as ordinary farmyard manure, weight for weight; consequently all serious attempts to deal with this material have been in the direction of eliminating as much of the moisture as possible.

At some sewage works the preliminary step in the separation of the liquid consists in running the sludge upon **roughly-contrived filter-beds,** composed of ashes screened from ordinary house-refuse; after a partial drying the sludge is mixed with more ashes, and when sufficiently hard and dry this "compost", as it is called, is carted on to the land and dug in as manure. This method is, however, very tedious, as in damp or wet weather the drying by evaporation is much retarded, and the handling and cartage also become expensive items.

At Ealing, near London, the sludge is mixed with the house-refuse and **burnt in an ordinary destructor,** the residuum being an innocuous and inoffensive "clinker". This method was also adopted at Salford, but the process is liable to produce offensive fumes, which must be specially dealt with.

At the Birmingham sewage-farm the sludge is simply **dug into the land,** whilst at Crossness on the Thames, where a large proportion of the London sewage is dealt with, the sludge after a partial natural drying is pumped into special hopper steamships and **carried out to sea,** where it is discharged into deep water; this latter method has also now been adopted at Salford.

The more modern method, however, of dealing with this necessary evil of all chemically-treated sewage, is to **pass it through a "filter-press".** The plant necessary in this case is a steam or other engine, working an air-compressor of such capacity as will compress the required amount of air to a pressure of about 100 lbs. on the square inch. The filter-press is usually made of vertical cast-iron plates, with recesses on each face and projecting rims, so that when pressed together there is a space between. The surface of each plate is furnished with cloths of jute, hemp, canvas, felt, or some such material, acting as a straining medium.

Fig. 426 shows the general appearance of a filtering-press of the pattern supplied by Messrs. Manlove & Alliott of Nottingham. The sludge is forced through the centre of the fixed end into the chambers between the plates, where the pressure is maintained until nearly the whole of the moisture has been forced through the filtering-pads and flows out by openings at the lower edge of the plates. When water ceases to flow, the hand-wheels are loosened, and the end frame is moved by the piston acted on by the compressed air, and the plates are separated one from the other by sliding them along horizontal shafts. The sewage-cakes, which have thus been formed between the pairs of plates, drop out, as the plates are moved, into a truck or other receptacle placed under the

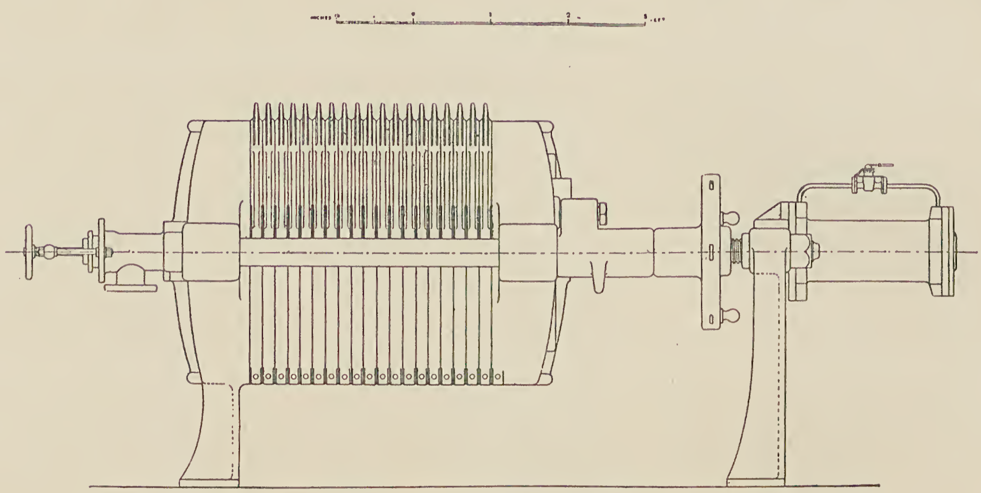

Fig. 426.—Elevation of Manlove and Alliott's Filter-press for Sewage Sludge.

press, and are removed to a suitable shed for sale as manure. The press is again closed, and the process of pressing resumed. Such a press as has been described is capable of turning out from 20 to 25 tons of cake per diem, at a cost of about 10*d.* per ton, the cake containing only about 50 per cent of moisture. About 5 tons of sludge can be pressed into one ton of cake, and this if dried and pulverized can be sold for about 2*s.* per ton. These figures will of course vary with the description of sewage dealt with and the chemicals employed, but it may be well to point out that it is generally found necessary to add from 3 to 5 per cent of lime to the sludge before pressing it, in order to prevent subsequent decomposition.

There is no doubt that sludge is the *bête noire* of all sewage-precipitation systems, and that very great difficulties are met with in storing and disposing of the mass of sludge which is made at all such sewage-disposal works.

CHAPTER V.

FILTRATION THROUGH LAND AND BROAD IRRIGATION.

Many were the early efforts to purify sewage by passing it through **mechanical filters,** either stationary, joggling, or rotating, but all these attempts, it is needless to state, were entirely unsuccessful, and experience has shown that it is impossible to filter sewage artificially, except through land or carefully-prepared bed-filters of suitable materials, and even then it is necessary to deal first with the sewage by some chemical or other process, in order to get rid of the sludge before reaching the filter, as otherwise this is soon choked and rendered inoperative.

It is true, however, that partially-successful purification of crude sewage has been obtained by what is known as **Intermittent Downward Filtration,** where a sufficient amount of suitable light land has been employed, but, in such a case, the treatment may be compared to broad irrigation. The land, however, in the former case is usually drained to a greater depth (6 or 8 feet), the drains are more frequent, and the soil (which must be of an exceptionally light nature) well broken up to receive the sewage. Where a large quantity of sewage has to be dealt with, in some cases equivalent to the sewage of a thousand persons per acre,[1] the land is not cropped, and the surface is frequently turned over in order to revivify it. No successful downward filtration of sewage through land or other materials can take place, however, unless the filtering medium is allowed to rest at intervals, in order that air, the great restorer, may enter the pores, and oxidize or burn up the organisms which have been at work eating up and destroying the organic matters in the sewage; and very little successful purification can take place, unless the sewage has previously been deprived of its heavier and slimy ingredients by some chemical or other precipitation process, as otherwise the sludge will eventually choke not only the surface of the filter, but sometimes even the interstices, and thus render the filter totally inefficient.

In some cases the surface of the land is formed into two or more series of narrow ridges and furrows, and by means of penstocks or syphons the sewage can be turned into the different series in succession. If osiers are planted on the ridges, a considerable quantity of sewage is absorbed by them.

[1] The eminent engineer, the late Mr. Mansergh, stated that no more than the sewage of 700 persons should be put upon 1 acre of land drained 6 feet deep. (Vide *Minutes of Proceedings of the Institution of Civil Engineers*, vol. xlix. p. 190.)

Dr. Frankland, in the First Report of the Rivers Pollution Commission, says, with regard to the filtering power of soils: "These results show how rapidly the process of nitrification (the conversion of ammonia and animal organic matter into nitrates) takes place in the Beddington soil, and how satisfactorily the sewage is purified, even at the rate of 7·6 gallons per cubic yard of soil per diem. But when this rate was doubled, the nitrification ceased, and the pores of the soil became blocked up, so that they would no longer transmit the whole volume of sewage applied and also afford time for aëration."

The limits of this article will not permit any further reference to intermittent downward filtration through natural soils; suffice it to say that good results can be obtained if the sludge is first removed from the sewage, and time is given to thoroughly aërate the soil before a fresh application of sewage is made. Dr. Voelcker says: "A well-drained and fully-aërated soil burnt up, or, in chemical language, oxidized most perfectly, the putrescible and nitrogenous organic constituents of sewage, and transposed them into nitrates and other final products of the decomposition of animal refuse matters, products having no smell, colour, or injurious properties".[1]

The disposal of sewage by **Broad Irrigation**, so called to distinguish it from Intermittent Filtration, still finds considerable favour with a great number of sanitarians, on the reasonable grounds that what is taken off the land ought to be put back on it, and that nature demands such a "circle of events". There can be no doubt that, theoretically, it is quite right that there should be no waste, and consequently the cry of "our sewage to the land or there will some day be no bread or meat" has much to commend it. Unfortunately the tendency of all civilized nations to congregate together in large centres makes it difficult to carry this worthy object into effect, and the difficulty of securing suitable and sufficient land within a reasonable distance of any large town or city makes it in most cases almost impossible, except at prohibitive cost, to dispose of the sewage by broad irrigation. The enormous bulk of sewage which has to be treated, its low manurial value owing to its dilution with water, its varying quantity with changes of the weather, and its unceasing flow day and night and at all seasons of the year, tend to complicate the problem of sewage-farming to such an extent as to make this method of dealing with sewage very unpopular except under exceptional circumstances. So far as experience can at present enlighten us, it is evident that commercially-successful sewage-farming is unknown, and that it is difficult enough, even under the most favourable circumstances, to deal with large quantities of sewage, especially during rain-storms,

[1] Vide *Minutes of Proceedings of the Institution of Civil Engineers*, vol. xlix. p. 191.

upon sewage-farms in a satisfactory manner, so as to secure an effluent which will not pollute in some measure the stream or river into which it flows. Dr. Lissauer after many experiments says: "The effluent water of irrigation-works ought not to be compared with good drinking-water, since it must nearly always contain some ammonia, often nitrates and nitrites, and always a certain amount of chlorine, which is almost completely unabsorbed by the soil".[1]

No doubt there are many instances **where there is sufficient land** available to so manipulate the sewage that portions of the land may be given intervals of rest, which revivifies them in such a manner that a very high standard of purity of effluent can be maintained, but these are fortunate circumstances not enjoyed by the majority of sewage-farms.

No hard-and-fast lines can be laid down as to **the quantity of land** necessary to ensure a successful sewage-farm. Much depends upon the character of the soil, whether light and loamy, or heavy and composed of clay. Much, too, depends upon the manner in which the farm is levelled, laid out, and drained. Much depends upon the climatic influences, and upon the quantity and quality of the sewage.

At Altrincham the sewage from a population of some 10,000 persons was dealt with on 10 acres of land for some months, and for many years the sewage of 11,000 persons was successfully dealt with upon only 47 acres of land. At Abingdon, 20 acres receive the sewage from 10,000 persons, and this form of sewage-treatment is still to the front. At the sewage-farm at Clichy, where the sewage of Paris is dealt with, about 9 million gallons of sewage per acre per annum are successfully dealt with, and in one case 35 million gallons were dealt with on one acre of land in two months.[2]

The following table shows very approximately **the amount of sewage** which was dealt with upon various sewage-farms, but these amounts are of course largely varied in times of heavy rain, and many of these places have since altered the treatment of their sewage to some form of bacterial treatment, which has within the last few years made enormous strides, and bids fair to supplant all other methods of sewage purification.

[1] Vide *Minutes of Proceedings of the Institution of Civil Engineers*, vol. lxvii. p. 356.
[2] *Ibid*, vol. xxxix. p. 380.

TABLE XXVI.

NUMBER OF GALLONS OF SEWAGE DEALT WITH PER DIEM ON VARIOUS SEWAGE-FARMS, PER ACRE.

Name of Place.	Gallons of Sewage dealt with in 24 hours per acre.	Nature of Soil.
Abingdon, ...	5,000	Loam.
Edinburgh, ...	10,000	Subsoil of sea-sand.
Banbury, ...	2,300	Stiff loam upon clay subsoil.
Cheltenham, ...	2,760	Clay.
Bedford, ...	4,516	Rich loam with gravelly subsoil.
Blackburn, ...	16,000	Light loamy soil upon gravelly subsoil.
Chorley, ...	5,747	Poor vegetable soil with stiff clay subsoil.
Doncaster	5,217	Light sandy soil.
Leamington, ...	2,950	Fine loam on gravelly subsoil.
Merthyr-Tydfil, ..	14,000	Fine loamy soil with gravelly subsoil.
Rugby, ...	6,153	Gravelly soil upon clay subsoil.
Tunbridge Wells, ...	3,000	Stiff loam and light subsoil.
Warwick, ...	5,185	Stiff clay.
Slough, ...	3,047	Sharp gravel and sand.
Barnsley, ...	16,886	Loam.
Aldershot, ...	1,960	Sand.
Croydon, ...	11,540	Open soil upon gravelly subsoil.
Berlin, ...	3,116	Sandy soil.

Professor Robinson says[1] that **the average cost of treating sewage on land,** at 26 sewage-farms examined by him, was 1*s.* 10½*d.* per head of the population, or about £7, 14s. 4½*d.* per million gallons of sewage.

The important points to be considered, in dealing with sewage upon the broad irrigation principle, are as follows:—

The position of the land with regard to the town, both as to locality and surroundings, and also its level, so as to avoid if possible lifting the sewage; the first cost of the land, and whether it is of suitable soil; the cost of the preparation of the land with regard to levelling, draining, and carrying the sewage to all parts of it—it is of the greatest importance that these should be carried out with great skill and perfection, as upon them, other considerations being equal, it depends whether the sewage can be properly purified or not; the choice of suitable crops and their rotation, and also whether there is a convenient market for the disposal of the produce. If there are no means of diverting the storm-water from the farm, very special means must be taken for dealing with it, as otherwise the land is overflooded at the very time when it is in a wet condition, and consequently in the worst position to receive so much liquid.

[1] Vide *Minutes of Proceedings of the Institution of Civil Engineers*, vol. xlix. p. 184.

There should be sufficient land, so that the various plots can be rested, not only when the crops are in a certain condition of growth, but also that the land may be revivified by the oxygen of the air, which is so important in all forms of sewage treatment.

The limits of this article prevent any discussion as to whether the produce grown on a sewage-farm, or the animals that feed on its produce, are injuriously affected by any pathological process. Suffice it to say that all attempts to prove any such injurious effects have hitherto failed, and that, with reasonable precautions and proper management, **a sewage-farm can be kept as healthy as any other farm.** Professor Forbes says: "There can be no question whatever but that, where the local circumstances of climate and soil are favourable to irrigation, and the conditions essential to its successful application properly observed, sewage irrigation is the most natural and effective system for the utilization of sewage, since it is only by this means that we can render available the whole of the ammoniacal salts, upon which so very much of the fertilizing value of the sewage depends".

There can be no doubt that the question of the disposal of the sewage of any town or building must be fully considered with all the surrounding circumstances, and each case requires careful and anxious enquiry and study before any decision can be arrived at. The sewage from a country house, for example, may be disposed of by the system of broad irrigation, if there is suitable land available at a sufficient distance from the house to prevent nuisance, but as a general rule it is better, even under these conditions, to run the sewage slowly through tanks before applying it to the land.

With reference to **the cropping of sewage-farms,** each case must be taken on its merits as regards suitability of soil, proximity to a town, climate, and other matters. There can be no doubt, however, that a sewage-farm properly managed produces most generous crops, as witness the following table of the results of a year's working of the Walton-on-the-Hill sewage-farm, which was under the control of the author, and which was well managed by the farm-bailiff in charge. The soil is a loamy clay, and the sewage was passed over the farm as it came from the sewers, without any chemical or other treatment. The main carriers were underground, and the greater portion of the farm was drained at a depth of about 5 feet, these drains converging into main effluent drains, which emptied into the river Alt. The effluent was free from solid matter, but did not reach the standard of purity required under the Rivers Pollution Acts, a fact which was not as important in this case as in others, as the waters of the Alt are not used in any way for domestic purposes.

Table XXVII.

WALTON-ON-THE-HILL SEWAGE-FARM—RETURN AS TO CROPS AND THEIR VALUE FOR THE YEAR 1896.

Plots.	Crop.	Acreage.	Quantity of Crop.	Average Price.	Gross Amount.	Per Acre. Quantity.	Per Acre. Value of Crop.
			Tons. cwts. qrs.		£ s. d.	Tons. cwts. qrs.	£ s. d.
1 & 3	Turnips,	10¼	254 11 1	10¼d. per cwt.	217 2 8	24 6 3	21 3 8
11 & 12	Scotch Cabbage,	13¾	5297 dozens	10¼d. per doz.	226 19 11	385¼ doz.	30 17 6
			Tons. cwts. qrs.			Tons. cwts. qrs.	
„	Do.	„	263 9 2	9d. per cwt.	197 11 0	19 3 1	
15	Cabbage-Savoys,	27¾	24 13 3	8¾d. „	18 4 11	0 17 3	
„	Do.	„	800 dozens	7¼d. „	23 14 2	28⅔ doz.	
„	Do. plants,	„	40,000	4s. per 1000	8 0 0	1441	16 7 9
			Tons. cwts. qrs.			Tons. cwts. qrs.	
„	Rye Grass,	„	655 16 3	7¼d. per cwt.	404 16 1	23 12 2	
6	Do.	6¼	280 12 1	6¾d. „	160 14 0	44 18 0	25 14 3
4	Rye Grass and Oats,	6¼	234 18 3	6¼d. „	129 10 5	37 11 3	20 14 6
5	Do.	10¼	174 3 2	5½d. „	82 14 5	16 19 3	8 1 5
10	Do.	14½	581 3 0	6½d. „	316 13 6	40 1 2	21 16 10

CHAPTER VI.

THE SEPTIC OR BACTERIAL SYSTEM.

Until recently **the processes by which decaying animal matter gradually disappears** were little known and less understood. It was known that chemical changes occurred, but how or why was beyond the chemist's power to explain. It is now, however, recognized that many of the chemical changes which take place in organic matter are closely bound up with the life-history of the micro-organisms, either animal or vegetable, generally known as microbes. There is no doubt that the disappearance of solids from sewage passed into a stream is in great measure brought about by micro-organisms. These feed on the organic matter and excrete it in a new form, its chemical composition as a rule being rendered simpler by the change. As a general rule, each species of micro-organism is poisoned or killed off by its own products; but the life-products of one species will generally serve as food for another. The breaking down of the solids in sewage thus forms a long chain of operations, though often accomplished in a marvellously short space of time.

In the Septic or Bacterial System no chemicals are employed, and there is no "treatment" of the sewage in the ordinary sense of the term, its purification being accomplished entirely by natural agencies.

The original Septic Tank, as designed and described by Mr. Cameron, was merely a receptacle designed to favour the multiplication of micro-organisms, and bring the whole of the sewage under their influence. To this end the tank was constructed of ample size, though not larger than would be necessary with chemical precipitation, and covered so as to exclude light, and, as far as possible, air. The incoming sewage was delivered below the water-level; and the outlet also was submerged, with the twofold object of trapping out air and avoiding disturbance of the upper part of the contents of the tank. On entering the still water of the tank, the solids suspended in the sewage were to a great extent disengaged, going either to the bottom or to the surface, according to their specific gravity. In the absence of light and air, the organisms originally present in the sewage increased enormously, and rapidly attacked all the organic matter. By their action the more complex organic substances were converted into simpler compounds, and these in turn were reduced to still simpler forms, the ultimate products of the decomposition in the tank being water, ammonia, and carbonic acid and other gases. Mr. Cameron claimed that no sludge need be formed, and described the bacterial action as follows:—"The larger part of the solids in the tank are found at the top, where a somewhat tenacious scum soon forms, consisting of the lighter solids in process of decomposition. The intensity of the action going on is evidenced by the large bubbles of gas, which everywhere break through the scum. Here is probably the chief seat of the bacteriological action, by which the solids are eventually thrown into solution. As soon as most of the organic matter in a solid substance is dissolved, the ash falls to the bottom, where decomposition continues its work. Presently a bubble of gas is formed, which buoys a fragment of ash and brings it again to the under side of the scum. The bubble soon becomes disengaged, and the ash falls again to the bottom. There is thus a constant interchange between the upper and lower layers of the tank, whereby its solid contents are brought under the most favourable conditions for rapid decomposition and solution. After a tank has been a short time at work, the scum increases in thickness very slowly. In one case, after thirteen months' work, the scum was only a few inches thick."

The effluent from the septic tank was turned on to filters, or bacteria beds, in which the effluent was held up for a certain period of time. Mr. Cameron's automatic gear for effecting this is thus described:—"The supply of effluent to each filter, and the discharge of the clear water after filtration, are controlled by valves, all connected to one rocking shaft; the clear water from each filter passes into a bed of gravel underlying it, from which it is led by drains into a collecting-well; as the effluent fills the filter, the clear water rises in the collecting-well,

and when the filter becomes full, a small quantity of clear water overflows from the collecting-well into a bucket carried by the shaft; the water thus thrown into the bucket bears it down the rocking shaft, and thereby actuates all the valves; the flow of effluent to the filter already full is stopped, and its discharge-valve opened, the effluent being turned on to the empty filter, whose discharge-valve is at the same time shut down. The water, rushing out from the filter last in use, draws down after it through the filtering material the charge of air required for dealing with the next dose of effluent. When the bucket which rocks the shaft sinks into its lower position, its contents are discharged through a counterbalance chamber, in which a part of the water remains to hold the valves in place until the other filter shall be full. The overflow from this second filter passes into another bucket, which was raised into position by the sinking of the first, and by means of which the valves are brought back into their original position."

Fig. 427 shows **the general arrangements of this septic tank and of the filter-beds,** but it ought to be stated that simpler mechanism has now been devised for throwing the contact beds or filters alternately out of use.

The analysis of the effluent from the filter of one of these works as taken by Dr. Rideal, was as follows:—

Table XXVIII.

ANALYSIS OF EFFLUENT FROM CONTACT BED

	Parts per 100,000.
Total solids, ...	76·8
Mineral matter, ...	57·1
Organic loss on ignition, ...	19·7
Chlorine, ...	7·28
Nitrogen as nitrates, ...	3·72
Nitrites, ...	strong
Free ammonia, ...	0·0124
Albuminoid ammonia, ...	0·044
Oxygen consumed in four hours at 80° F., ...	0·324
Total organic nitrogen,[1]	0·066

Dr. Rideal, in a paper which he read before the Sanitary Institute in December, 1896, on "The Purification of Sewage by Bacteria", stated, in connection with Mr. Cameron's septic process, that radical changes take place in the tanks, produced by the bacteria which are present in the raw sewage, and whose growth is favoured by the absence of light, air, and comparative absence of movement.

[1] The Rivers Pollution Commissioners allow up to 0·3 organic nitrogen in an effluent passed into a river.

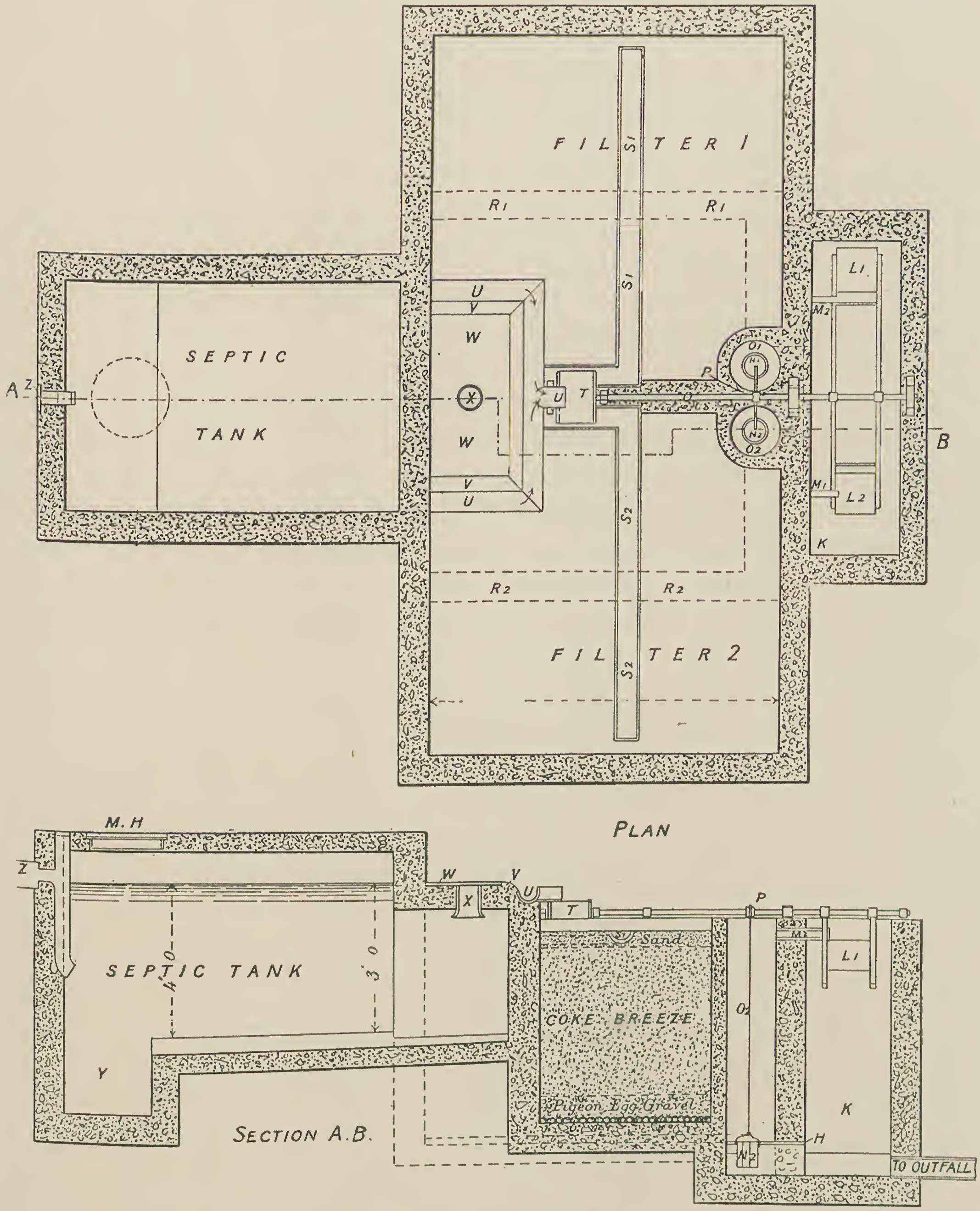

Fig. 427.—The Original Septic Tank System of Sewage Treatment.

Z. Inlet to septic tank. *Y.* Sump for grit. *X.* Outlet to septic tank. *W.* Table top. *V.* Weir. *U.* Channel pipe collecting effluent after passing over weir. *T.* Diverter. *S1, S2.* Channel pipe distributors over filters. *R1, R2.* Culverts at bottom of filters. *Q.* Shaft. *P.* Rocker. *O1, O2.* Wells for discharging valves. *N1, N2.* Discharging valves. *M1, M2.* Overflows from wells to actuating tanks. *L1, L2.* Actuating tanks. *K.* Well for actuating tanks. *H.* Cast-iron plate with seatings for valves *N.*

He summarized the results of a series of experimental analyses, which he had carried out, as follows:—

"(1) A marked increase in the total solids in solution or fine suspension.

(2) A reduction of about 33 per cent of the organic matter as measured by the oxygen consumed.

(3) An increase of about 33 per cent in the free ammonia.

(4) A reduction of about 54 per cent in the organic or albuminoid ammonia, or 50 per cent of the organic nitrogen.

(5) A slight production of oxidized nitrogen, and a disappearance of a small amount of the total nitrogen."

These changes are effected by means of the bacteria, enzymes, or spontaneous chemical decomposition in the tank, and Dr. Rideal was of opinion that the septic tank effected as much purification as an average chemical precipitation process, or as slow upward filtration, and "that the solid fæces and other matter in suspension pass into solution in the septic tank".

In the fifteen years that have elapsed since the "Cameron" experimental Septic Installation was constructed at Exeter, considerable developments have followed, but they are all practically on the same lines, viz., first a tank, covered or otherwise, and then bacteria beds or filters where the tank effluent is further treated. It will be well to endeavour to explain the process at more length, showing the various modifications and rules where possible.

The Tank.—The sewage flows into a tank which for convenience of cleansing should be divided into two or more compartments. The size of this tank should be such that its total working capacity should be equal to about one day's dry-weather flow.

The sewage should enter below the top of the sewage in the tank. The tank may be covered or not. Some experts advocate a covered tank as helping the anaerobic action which plays so important a part in this septic or liquefying tank; but it is doubtful if there is a great deal in this contention: anaerobic action appears to go on equally well in an uncovered as in a covered tank. Owing to this action, however, the contents of such a tank are very offensive, and if nuisance is to be avoided the tank should be covered. The depth of sewage in the tank is of some importance, as it should be sufficiently deep to avoid much disturbance of its contents when there is an extra rush of sewage, due to rain-storms or other causes. The effluent from the tank should be taken from below the surface in the same manner as the sewage enters the tank.

The next question is **the treatment of the effluent.** This is generally effected in one of the following manners:—

(*a*) By storage in **primary** and **secondary beds.**

(*b*) By passing it through **streaming** or **percolating filters.**

(*a*) In this case **contact beds** are constructed and filled with clinker, coke, broken stones, or other suitable material, in which the effluent is allowed to rest for a certain period, and where the aerobic action follows the anaerobic action of the tank.

The size, depth, and material of which these beds are formed are very various, and there is yet no universal custom. What is striven to be arrived at in their construction is that their cubical capacity shall be sufficient to ensure that every portion of the effluent shall come in contact with the greatest number of the aerobic or nitrifying germs contained in the bed. Whereas the size of the tank has been settled at a capacity equal to the dry-weather flow of one day's sewage, the capacity of those primary beds must be equal to three times this quantity, for reasons that need not be mentioned here. The depth of these beds should not be less than 3 feet, and perhaps not more than 6 feet, but, as has been already stated, experts disagree considerably on many of these points of detail.

The filling and emptying of these beds should, if possible, follow a cycle of the following kind:—

Filling	$1\frac{1}{2}$ hours.
Resting full	3 "
Emptying	$1\frac{1}{2}$ "
Resting empty	2 "

It is of the utmost importance that the bed should be thoroughly drained, no effluent being allowed to remain at the bottom of the bed.

From these primary beds the effluent is frequently further treated in **secondary contact beds,** the beds being similar in all respects to the primary beds, except as regards the size of the "filtering" media. The word "filtering" is generally used, though it appears to be somewhat of a misnomer; the author would suggest "bacterial" medium as being more appropriate.

Bacterial Media.—With regard to this medium, experts are again somewhat divided in their opinion, as to the best material to be employed and the sizes to which the material should be reduced. The consensus, however, of modern opinion appears to be that the material should be hard and free from dirt or dust, and that the size should be not smaller than that which will pass through a $\frac{1}{4}$-inch, or larger than that which will pass through a $\frac{3}{8}$-inch screen.

The cost of suitable material must be considered, so that the selection of such a material must be in a large measure dependent upon the locality. Amongst various materials which have been used for the purpose may be mentioned: coke, coal, clinker, engine ashes, saggars (from pottery works), slate (recommended by Dibdin), hard gravel, and granite. The material selected should be sufficiently hard not to disintegrate, and at the same time have sufficient cavities or small caves in which the countless colonies of bacteria may be housed.

With regard to **the capacity of these beds,** the liquid capacity is, roughly speaking, about one-third of the gross capacity, but as there is a cycle of three fillings in the twenty-four hours, the gross capacity of a bed represents its daily working capacity.

The proper working of the beds has to be regulated either by hand or by automatic machinery. There are a large number of ingenious arrangements by which automatic working is effected, but they all require somewhat skilled attention, without which they are liable to get out of order. Automatic syphons are often used for the purpose. The effluent syphon is placed in a small chamber, and its inlet arm is taken through the wall of the chamber to the bottom of the contact bed. A small pipe is also fixed through the wall of the chamber at a higher level, and on the end of this a cock is fixed; by means of the cock the flow of sewage into the chamber can be regulated to give the required period of rest to the sewage in the bed, as the syphon will not begin to empty the bed until the sewage in the chamber has reached a certain level. A number of syphons may be connected in such a way as to discharge a series of beds in rotation.

(*b*) **Streaming or Percolating Filters.**—In this case the tank effluent is not held up in a bacterial bed, but is allowed to stream continuously through the bed, which is composed of similar material to that of a contact bed. Here again experts are divided as to the depth necessary, and the means by which the effluent shall be applied to the bed so as to get the best possible result and purification. The earlier beds were made of considerable depth, in some cases as much as 12 feet, but modern practice tends to reduce this depth, and from 3 feet to 4 feet is now generally accepted as giving the best result. Dr. George Reid, who is a well-known expert on this question, has, however, from recent experiments, demonstrated that with a certain class of sewage and an excellent bacterial medium (viz. broken saggars), and with a tank effluent mechanically distributed thereon in the best manner possible, a very high standard of purity has been rendered by passing the tank-effluent

through only 1 foot 6 inches of the depth of a streaming filter. Whether this would be possible in all cases remains to be seen, but if so it will tend to further simplify the question of sewage purification and greatly reduce the cost. Various methods of distributing the tank-effluent on to the filter have been devised, the inventors thereof claiming that each of their methods is the best. Some are mechanically-driven spreaders, whilst others derive their motion from the head of the tank-effluent itself.

Where the filter is circular, the most common practice is to erect **a rotating sprinkler,** which acts under the well-known law of "action and reaction", the issue of the effluent from the nozzles in the spreading arms driving the spreader in the opposite direction. The objections to this method are:

(1) A sufficient head (about 2 feet) is required to drive the sprinkler, and this head cannot always be obtained.

(2) A high wind affects the rate of speed, or may entirely stop the spreader.

(3) The distribution is not very even or regular.

Consequently, **electrically-driven spreaders** for larger installations have been introduced with good results. One considerable advantage is that the bacteria beds may be constructed rectangular instead of circular; the spreader or distributor can also be retarded or accelerated according to the dose required, and the desired speed can be maintained without fluctuation.

Rate of Filtration.—As to the quantity of tank-effluent that can be put through a percolating bacteria bed, the Local Government Board have at present decided that this may be at the rate of 56 gallons per square yard of surface of bed per foot of depth, where the effluent can be further subjected to final land treatment, and only 28 gallons where the effluent has no final land treatment.

It may here be convenient to state the present **regulations of the Local Government Board** in connection with the disposal of sewage. In any sewage scheme the whole of the sewage up to six times the daily ascertained dry-weather flow (technically known as D.W.F.) must be taken to the sewage disposal works for treatment. Any excess of this amount due to abnormal rain-storms may be passed over fixed weirs into convenient water-courses or streams, as this excess is held to be sufficiently diluted to be practically fit to be so disposed of without treatment. This leaves six times the D.W.F. to be dealt with. Of this quantity, in the case of districts sewered under what is known as the "separate" system (*i.e.* where the rain-water from streets and roads and front roofs, &c., is taken into separate surface-water sewers), four times the D.W.F. must be specially treated as weak sewage, and two

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Rate of Filtration.—As to the quantity of tank-effluent that can be put through a percolating bacteria bed, the Local Government Board have at present decided that this may be at the rate of 56 gallons per square yard of surface of bed per foot of depth, where the effluent can be further subjected to final land treatment, and only 28 gallons where the effluent has no final land treatment.

It may here be convenient to state the present **regulations of the Local Government Board** in connection with the disposal of sewage. In any sewage scheme the whole of the sewage up to six times the daily ascertained dry-weather flow (technically known as D.W.F.) must be taken to the sewage disposal works for treatment. Any excess of this amount due to abnormal rain-storms may be passed over fixed weirs into convenient water-courses or streams, as this excess is held to be sufficiently diluted to be practically fit to be so disposed of without treatment. This leaves six times the D.W.F. to be dealt with. Of this quantity, in the case of districts sewered under what is known as the "separate" system (*i.e.* where the rain-water from streets and roads and front roofs, &c., is taken into separate surface-water sewers), four times the D.W.F. must be specially treated as weak sewage, and two

times as foul sewage. Where the sewerage is on the "combined" system (*i.e.* where the rain-water enters the "foul" sewers), the division is three times the D.W.F. to be treated as weak sewage and three times as foul sewage. The method of separation at the disposal works must be by a fixed weir or weirs; no movable penstocks or other arrangements are allowed. The "weak" sewage may be dealt with on a special area of land, the amount of "weak" sewage allowed per square yard of this area depending upon the description of the subsoil, or it may be passed through special "filters" at the rate of 500 gallons per square yard, the filter being about 3 feet in depth. This leaves either three times or two times the D.W.F. to be treated as foul sewage as the case may be.

In addition to this, in many cases, there may be considerable quantities of "trade effluents" discharging into the sewers. Provision must be made for this by adding the ascertained daily normal flow of these trade wastes, plus one-tenth, to the quantity of sewage to be dealt with as foul sewage.

The Local Government Board have further decided as to the capacities of the various tanks and filters. The capacity of the special "excess" filter has been given, viz. 500 gallons per square yard. The tank capacity must be about one to one and a quarter times the D.W.F. The contact beds must be either three or two times the capacity of the D.W.F. plus the provision for trade effluents, if any. The streaming filters must be worked at a rate not exceeding 56 gallons per square yard per foot of depth where there is subsequent land treatment, or 28 gallons where there is no subsequent land treatment.

Whether the result of the labours of the Royal Commission on Sewage will render it necessary to alter these figures it is impossible to say, and whether the figures are too arbitrary, as some experts consider, is not for the author to say; but these figures have been arrived at after much careful consideration of all the circumstances, and where followed in the preparation of schemes, have been attended with success.

The author will not go into the rather technical question as to whether the present "bacterial" processes eliminate from the effluents those "colloidal" matters which are said to remain in many of the treated effluents, nor will he deal with the much discussed question as to whether in some cases it is better to treat the sewage chemically before bacterial treatment or not. It is perhaps sufficient to say that each case must be scientifically investigated before a scheme is designed, and that every year brings to light more improvements in this important question of the proper purification of our sewage. The

effluent obtained by a good bacterial system of treatment cannot safely be used as "drinking water", but as a general rule it is equal to the reasonable standard of purity demanded by the county councils or other bodies whose duty it is to prevent the pollution of our rivers.

CHAPTER VII.

SEWAGE-DISPOSAL FROM HOUSES NOT CONNECTED WITH ANY SEWERAGE-SYSTEM.

Having thus far dealt with the general question of the disposal of sewage, it is necessary to say a few words upon that very difficult problem of **the disposal of sewage from isolated houses,** which have not the advantage of being connected with any general system of sewerage. A number of the previous remarks will apply in considering this question, but, of course, unless the isolated house is a large establishment, such as an asylum, hospital, gaol, hotel, school, large mansion, or something of the kind, it would be an expensive if not an altogether unwarrantable proceeding to adopt a chemical precipitation process for dealing with the sewage; nor might it be possible, on the other hand, to find sufficient land to take the sewage on the irrigation or filtration system, although in some cases, even where there is but little available land, this latter method might be advantageously adopted, and the remarks in the preceding pages on these systems are worthy of attention in connection with this question. Let us, however, deal with the problem of the disposal of the sewage from an isolated cottage or small residence.

Hitherto the methods mostly adopted in connection with such houses have been either privy-middens or cesspools, as being the most convenient and least expensive methods for getting rid of the sewage-matters. With regard to the former method, all the necessary remarks will be made in the next chapter. The cesspool and other methods of dealing with liquid sewage will now be considered.

The cesspool has been found—and is still found—to be the most convenient method for disposing of the sewage from isolated establishments, but it is almost unnecessary to state that such an arrangement is barbarous and insanitary, where, as in the majority of cases, the cesspool is both badly situated and wretchedly constructed. Other books have dealt at length with the evils arising

from ill-designed and badly-situated cesspools, especially that delightful book on *Dangers to Health*, by T. Pridgin Teale, M.A., so that it is unnecessary to say more upon the subject, but rather to point out what considerations are necessary to mitigate as much as possible this, at present, requisite adjunct to many houses; and it will be the object of these pages to endeavour to point out some of the more modern methods for effecting this purpose.

The choice of position must be guided by the available land, the position of the house, the gradient of the land, and above all by the "dip" of the subsoil-strata and the position of the well or water-supply. If the cesspool is to be emptied by the local authority, it ought to be within reasonable distance of the road, and as far from the house as practicable, in order to render the operation of emptying as little of a nuisance as possible. Proximity to the road has the additional advantage that extensive reconstruction of the drains will not be required when the laying of a public sewer in the road has provided better means of disposal than those afforded by a cesspool. The minimum distance between a cesspool and a house or other building intended for human occupation is prescribed by the by-laws or regulations in many districts. In some old by-laws still in force the minimum distance is 30 feet, but as a rule it is now 50 or 60 feet, and in some towns 100 feet.

Having settled the position, it is necessary to consider **the size of the cesspool.** This will, of course, be governed by the daily quantity of the flow of the sewage, and the interval of time to be allowed between each cleansing of the cesspool. The quantity of the daily flow depends upon the number of persons inhabiting the house, and the water-supply. That great sanitarian, Dr. Edmund A. Parkes, in his *Manual of Practical Hygiene*, states that "in poor families who draw water from wells, I have found the amount to vary from 2 to 4 gallons per head, but then there was certainly not perfect cleanliness"; and further on he states, after quoting various authorities, "I believe we may safely estimate that for personal and domestic use, without baths, 12 gallons per head daily should be given as an usual minimum supply, and with baths and perfect cleanliness 16 gallons should be used. This makes no allowance for water-closets or for unavoidable waste."

These observations of Dr. Parkes perhaps do not hold good to the present day, as where a water-supply is laid on the daily quantity used may rise to 25 or 30 gallons per head per diem; but, as $6\frac{1}{4}$ gallons of sewage equal a cubic foot, the dimensions of the cesspool can be easily calculated, when we know the exact amount of daily flow from a given number of persons, and have decided how often the cesspool should be emptied. If any part of the rainfall enters the

drains, the calculations will be somewhat more complicated, but, for obvious reasons, it is always best to exclude rainwater from cesspools.[1] Authorities on this subject state that a cesspool should be emptied at least once a week, but, owing to the nuisance and expense of this operation, much longer intervals are allowed to elapse between the cleansings, and this is specially the case where there is (very improperly) an overflow from the cesspool into an adjoining ditch or stream, or where, as in the majority of cases, the cesspool is steined with open brick or stonework so as to allow the liquid contents to soak into and pollute the surrounding soil.

Having then settled the dimensions, it is necessary to design **the shape of the cesspool.** It is found geometrically that the largest area is obtained, with a given amount of material, by a circular chamber, and in addition to this such a shape has considerable resisting power, and, if properly designed, is more easily cleansed. Thus, for a simple cesspool, the design shown in No. 1, fig. 428, meets most of the requirements. In districts having a subsoil of dry chalk or gravel, or of impervious clay, the construction of a deep cesspool is not a difficult matter, but in water-logged ground the cost of such a cesspool would in many cases be prohibitive, and it is then better to build a shallow oblong tank in order to reduce the expense of pumping out the water during construction. The drains should also be laid as near the surface of the ground as possible, and as cast-iron pipes can safely be laid with flatter gradients and nearer the surface of the ground than stoneware pipes, the former may be used with advantage. The saving thus effected in the excavations for the drains and cesspools will go a long way towards paying for the extra cost of the metal pipes.

The construction of the cesspool is a matter of great importance. In order to make it water-tight, it is a good plan to excavate the ground sufficiently wide that the cesspool can be surrounded with at least 6 inches of well-puddled clay. It is almost unnecessary to say that it should have a foundation of Portland-cement concrete and be built of good hard bricks (better lined throughout with Staffordshire blue bricks), set in Portland-cement mortar. The walls and bottom are usually rendered with Portland-cement mortar. The top may be formed in the shape of an arch or dome with bricks in cement mortar, or if the cesspool is shallow and near the surface of the ground, it may be covered with concrete reinforced with steel and rendered on the upper surface with cement mortar. Every cesspool should be provided with a hermetically-closed iron cover for access for cleansing.

[1] For particulars of rainfall, see § III., "Water-Supply".

The ventilation of the cesspool is a matter of great importance. Nearly all by-laws now in force specify that a cast-iron or other approved ventilating pipe, not less than 4 inches in internal diameter, must be carried up from the cesspool to a height which will afford a safe outlet for foul air. In some cases the minimum height allowed is 10 feet above the ground. The open top of the

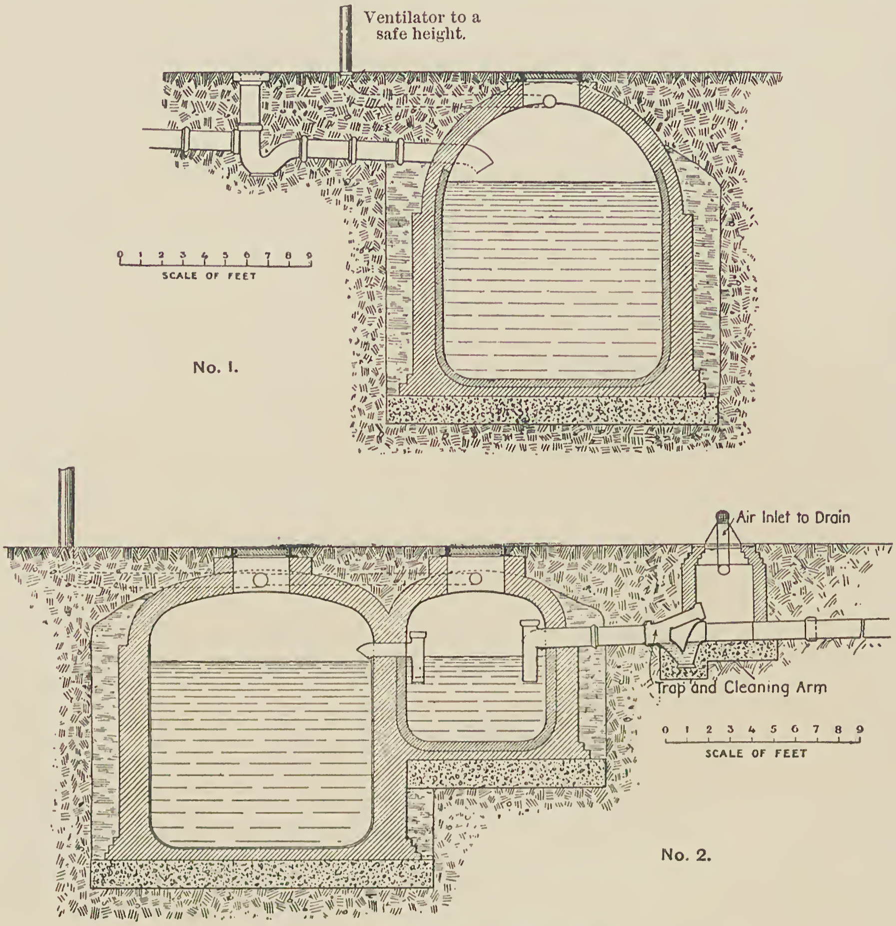


Fig. 428.—Sections of Single and Double Cesspools.

pipe should be protected by a balloon-shaped guard of copper wire to prevent the pipe from being choked with leaves, &c. The cesspools shown in fig. 428 are ventilated by vertical pipes of this kind.

The drain from the house should be trapped and ventilated near the cesspool, exactly in the same way as if the cesspool was a public sewer. The intercepting chamber shown in No. 2, fig. 428, is more convenient than the pipe shaft shown in No. 1, although the latter may safely be used for very shallow drains.

If there is no available land or other safe method for dealing with **the liquid overflow from the cesspool,** no overflow should be allowed, and the cesspool must be oftener cleansed. If, however, there is sufficient land, the overflow may be directed over alternate filter-beds of either gravel, suitable soil, or coke-breeze, in one of the ways to be described later. In this case, however, the cesspool serves the purpose of a septic tank, and must be of less capacity than an ordinary cesspool, and must indeed in all respects be

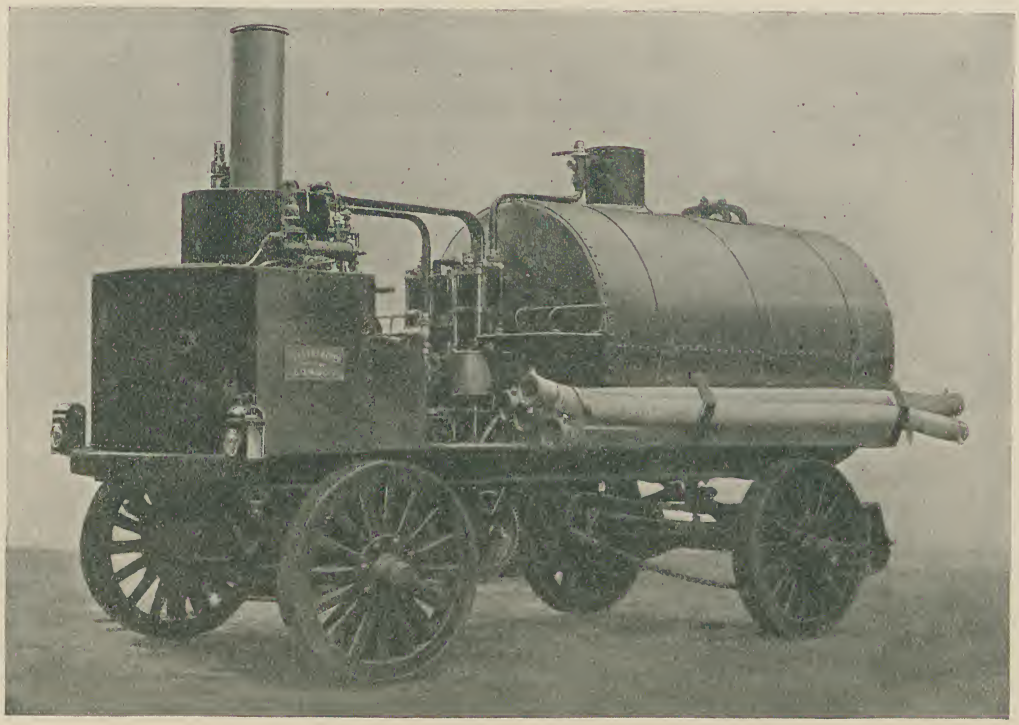


Fig. 429.—Merryweather's Pneumatic Cesspool-emptier.

designed and constructed as a septic tank. Where no overflow can be arranged, the cesspool would be better if constructed in duplicate, as shown in No. 2, fig. 428. The first compartment may with advantage be constructed as a septic tank to hold one day's flow of sewage, the inlet and overflow pipes being dipped as shown to prevent undue disturbance of the contents. Much of the solid matter present in the crude sewage will be broken up and liquefied or converted into gases in the first compartment, and the sewage in the second compartment can be pumped out and may on occasion be used with due care in the kitchen garden or on any other available land.

The cleansing of cesspools is always a disgusting and troublesome process, and is generally effected at night. It is usually done by hand labour, the

contents being taken out in buckets or pumped into carts or wagons, either open or covered, and carried off to be deposited on land or into pits, or otherwise dealt with. This method of emptying cesspools is essentially crude and unscientific, and a more modern method is that now adopted of employing a special vehicle for the purpose. The ordinary vehicle is drawn by a horse, and consists of an iron tank on wheels, from which the air is abstracted by a manual pump; a hose attached to the vehicle is inserted into the cesspool, a stop-cock on the hose is opened, and the tank is filled by the pressure of the atmosphere without causing the slightest nuisance. Messrs. Merryweather have designed a steam motor cesspool-exhauster, which is shown in fig. 429. The tank is exhausted of air till a vacuum of about 15 inches is reached, by means of powerful air pumps driven by the motor. The suction pipes, which are carried in brackets on the sides of the tank, are screwed to the rear valve and the end placed down the manhole of the cesspool. All connections being tight, the inlet valve is opened and the sewage is drawn into the tank. The air pumps are kept running during the operation, the exhaust air being sent through the furnace in the boiler to deodorize it. As soon as the cesspool is empty the inlet valve is again closed, and the machine travels forward to its next job.

A substitute for the country cesspool is often found in the disposal of the sewage on land. If agricultural land is not available, a plot of garden will suffice. It is not generally understood how small the plot may be. The area of ground generally accepted as sufficient for the purification of sewage by "Intermittent Downward Filtration", is one acre for the sewage of 700 to 1000 persons; a patch of garden 6 yards square will therefore suffice for the purification of the sewage from an ordinary household of five or six persons. The ground must, of course, be of a suitable nature and be suitably prepared. An interesting method of preparation is that adopted by Dr. G. V. Poore, and described by him in a paper on "The Treatment of Domestic Slop-water in Isolated Houses", read before the Sanitary Congress in Leeds in 1897. The "filtration-gutters", which he advocates, for the disposal of domestic slop-water, have been successful far beyond his expectations, and are constructed as follows:—

"A trench two feet deep and eighteen inches wide, and of a length varying with the circumstances, is dug and filled up with porous material, such as builders' rubbish, old crockery, and tins, stones, &c., to within a few inches of the surface, and upon this rubbish, previously rammed, walls of concrete or honeycomb brickwork are formed, provided with a ledge sufficiently wide to support a perforated tile, the perforations being big enough to admit a large-size knitting-needle, say one-eighth of an inch in diameter. The porous rubbish

reaches to within an inch of the underside of the tile, and the sides are planted. The gutter may, if necessary, be protected with a grating." The description will be better understood on reference to the plan, elevation, and section given in fig. 430. Dr. Poore says that the gutter may with great advantage be

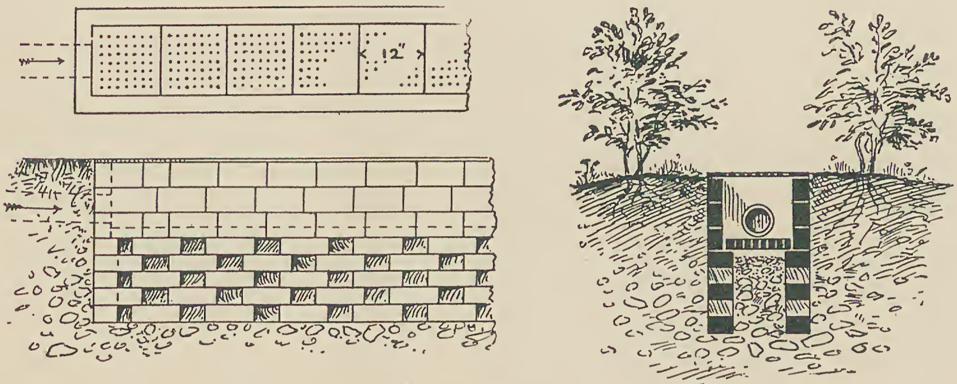


Fig. 430.—Plan, Section, and Elevation of Filtration-gutter.

placed upon a bank with gradually-sloping sides, as shown in fig. 431. This arrangement is "necessary on clay soils".

The perforated tiles forming the bottom of the gutter are those made for the floors of malt-kilns; they are an important part of the system, as they retain dead leaves and other rubbish and prevent them clogging the porous material below, besides breaking the force of the sewage, and so preventing "the downpour from the pipes from ploughing up the rubble, which is a most important matter".

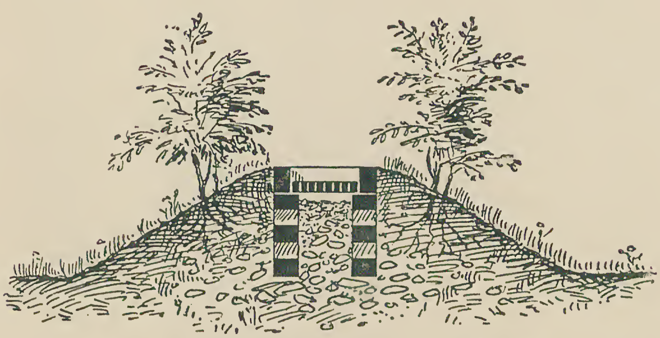


Fig. 431.—Section of Filtration-gutter for Clay Soils.

The ground on both sides of the gutter should be planted with quick-growing shrubs, but there is no reason why vegetables should not be grown if desired.

An example of the working of one of these filtration-gutters will be interesting. After two years' experience, Dr. Poore wrote, "I constructed such a gutter for a girls' school where there are between thirty and forty day-scholars and boarders. I dug out my trench leading into a natural rivulet, and I formed a gutter forty feet long. I do not think the slops in this case

have ever travelled as much as six feet, and there is no evidence that a drop of slop-water has ever touched the rivulet. The privets have grown, but the gutter has never been foul, and when the tiles have been taken up, the porous rubbish beneath has been found perfectly sweet, and there has been no sloppiness at the sides."

Other examples were given by Dr. Poore, but need not be described in detail. It would, however, have been interesting to know the nature of the soil and subsoil in the several cases, and also whether there was the slightest reason to fear the pollution of the subsoil. As the sewage never travelled more than 6 feet along the 40-feet gutter, it might be more advantageous to construct two shorter gutters (say) 20 feet long, parallel to each other, and so arranged that the sewage could be turned into either of them, the other being at rest for aeration or repairs.

It should be pointed out that Dr. Poore did not advocate the passing of **the wastes from the kitchen and pantry sinks** into the drains without preliminary straining and filtering. These operations can be performed by means of a filter containing two compartments, each 1 foot by 1 foot 6 inches and 2 feet 6 inches deep, and filled with fine gravel. The waste-pipes must discharge over this filter, one compartment being at rest while the other is in use.

Dr. Poore's filtration-gutters are, it must be remembered, intended to purify "domestic slop-water" only, and not for **the purification of sewage containing excreta.** Where the system is in operation earth-closets are used, and the excreta are trenched into the ground in the garden. It would not be advisable to pass sewage containing excreta into such filtration-gutters, as this would inevitably lead to the stoppage of the small holes in the tiles, besides proving a nuisance if near the house. A preliminary straining chamber might be constructed of impermeable materials to intercept the solid matters; it would require to be carefully covered, and very small, so as to necessitate frequent cleansing. A more satisfactory method, however, would be to pass the sewage through a septic tank, and to treat the effluent from this in the filtration-gutters.

In many cases **a simple bacterial system of purification** provides a better way of dealing with the sewage of a house than that of conveying it to a cesspool with all the attendant dangers of such a receptacle. One of the latest domestic sewage-disposal plants, and one that is simple in its operation, is shown in fig. 432. The receiver or chamber is made of a convenient size, and of such a capacity that the solids are retained therein and partly "digested" or liquefied, without setting up excessive septic action, which is always liable

to create an offensive smell. The effluent from this receiver passes out through a submerged outlet on to an automatic tipper, which discharges its contents on to a distributing tray formed of angle-irons set at short distances apart so as to form a number of long, open slots, through which the effluent, after being broken up on the ridges of the angle-irons, is distributed in drops evenly over the whole surface of the filter underneath. It is claimed that there are no small holes in such a distributor liable to become choked, and that it is so simple and reliable that all that is required is to occasionally sweep down

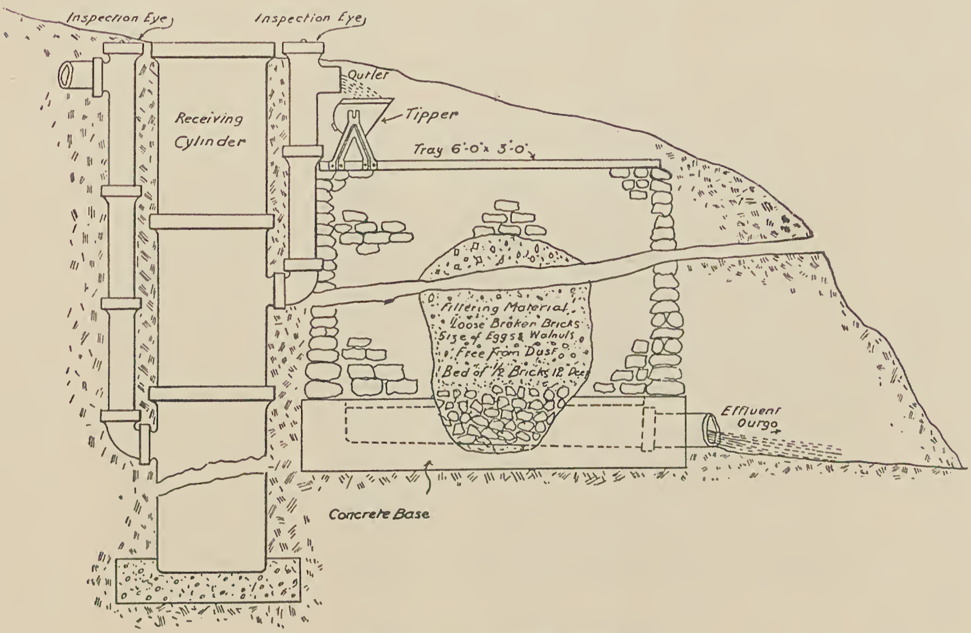


Fig. 432.—The Adams Domestic Sewage Plant.

the tray with a broom. It is also necessary to remove occasionally some of the scum and sludge in the receiver, and to see that the top layer of the filter is clear of leaves or other obstructions. This can, of course, be done by an ordinary labourer or gardener. The filter acts as a "percolating" filter, and should be not less than 4 feet in depth if the fall of the land permits. The area of the filter depends on the quantity of sewage with which it will have to deal. It is stated that a filter 4 feet in depth can produce a perfectly clear effluent at the rate of 250 gallons of sewage per square yard per twenty-four hours.

The bottom of the filter should be formed of concrete or brickwork, and slope slightly towards the centre. The bottom layer of filtering medium should consist of large pieces of stone, brick-bats, or other suitable material laid

about 9 or 12 inches in depth, allowing rather large interstices for efficient drainage and aeration, as it is of the utmost importance that all the moisture should drain out of the filter in order to ensure a proper purification of the sewage. The remainder of the filtering medium should be, preferably, of hard furnace clinker, varying in size from $\frac{3}{4}$-inch to 2-inch gauge, the larger at the bottom, and gradually getting smaller towards the top; nothing less than $\frac{3}{4}$-inch gauge should be used, and all dust and dirt should be carefully excluded by screening and washing. It is contended by the designers and manufacturers of this plant (Messrs. Adamsez, Limited) that a remarkably good effluent

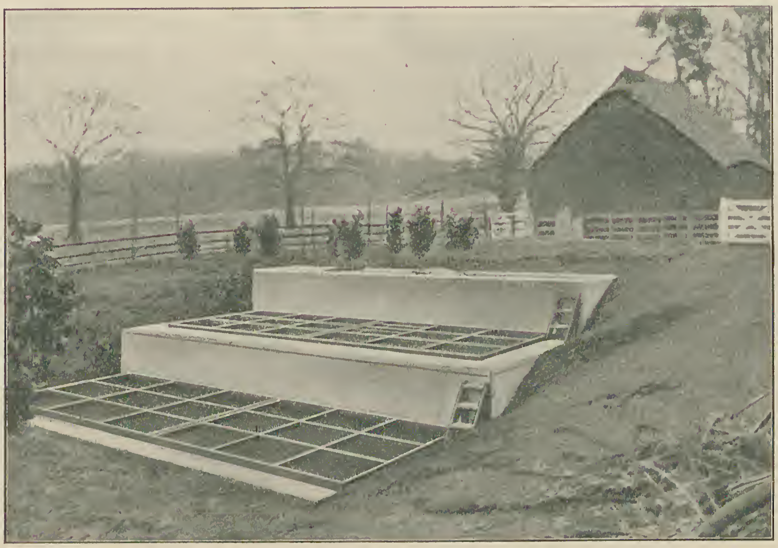
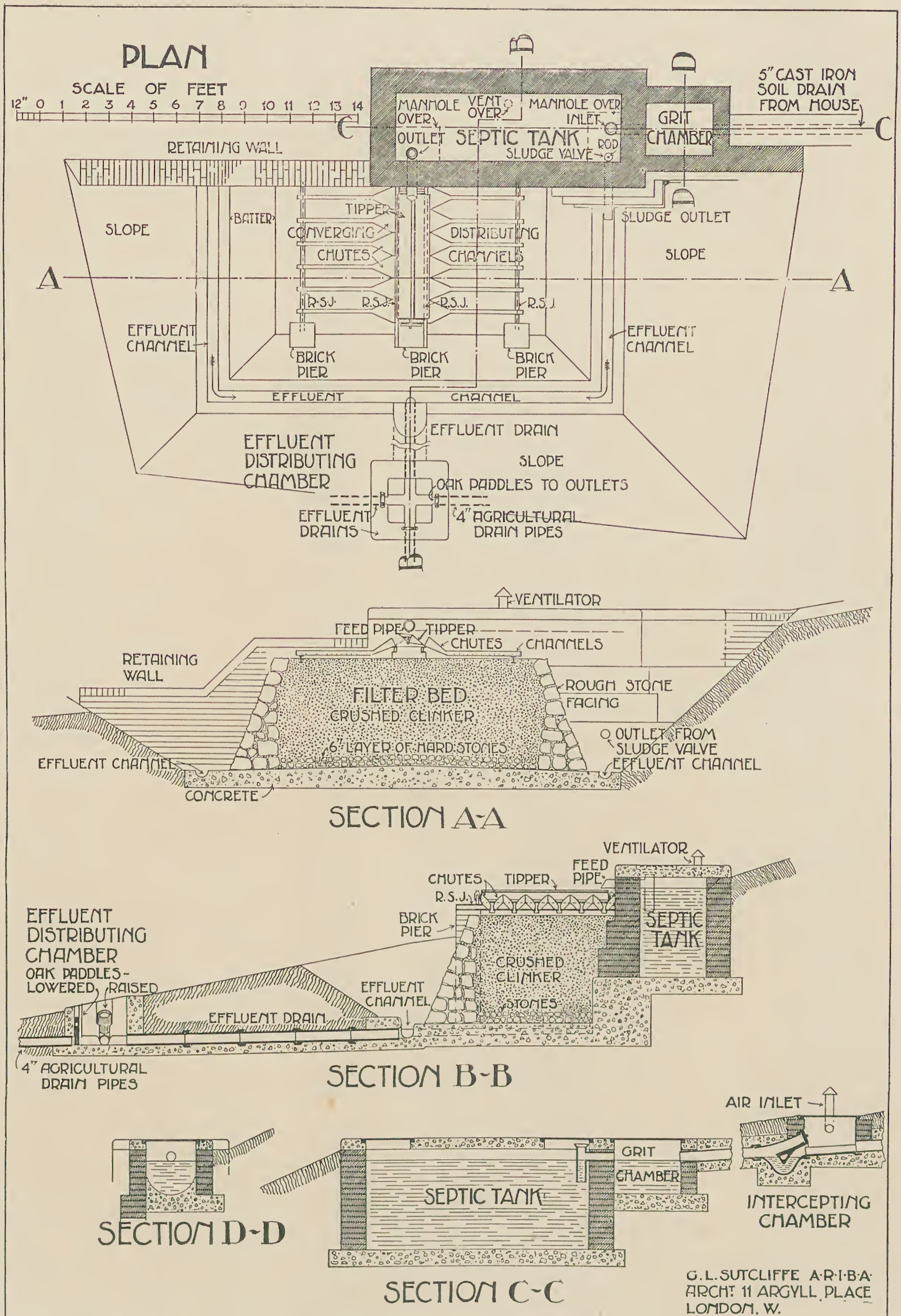


Fig. 433.—Double Contact-beds at The Hermitage, Windsor.

can be obtained by such an installation, and that no nuisance, or the slightest smell, is occasioned thereby; that it is so simple as to be "fool proof", and can be kept in order with a modicum of attention. For an installation of this description, dealing with the sewage from about fifteen persons, the cost of the receiver, automatic tipper, and distributing tray is stated to be £25; the cost of the filter is, of course, dependent on the value of labour and clinker in any particular neighbourhood.

A rather more extensive installation, carried out by the same firm on somewhat similar lines, is shown in fig. 433. This is a photograph of an installation constructed for dealing with the sewage from the Duke of Newcastle's house at The Hermitage, Windsor. It was designed by Messrs. D. Balfour & Son, civil engineers, of Newcastle-on-Tyne, and is capable of dealing with 5000 gallons of sewage per diem at three fillings a day of the contact beds. This maximum



BACTERIAL SYSTEM OF SEWAGE PURIFICATION

FOR COUNTRY HOUSE IN SURREY

quantity has only to be dealt with for a few days in the year during Ascot week, and for the rest of the year the daily flow is only about 500 gallons.

This installation had to be specially designed to meet the fluctuating flow, and is able to do so by the introduction of a "collecting" tank actuated by "Adams" alternating syphons. The collecting tank is equal to the liquid capacity of one of the contact beds. There are two syphons in this collecting tank, which discharge alternately into the two "primary" contact beds. There the effluent is held up by "Adams" timing syphons for the proper period (about two hours), and is then automatically discharged into the fine-grained "secondary" beds. There the effluent is similarly held up, and is then discharged into a ditch. The collecting tank is covered with 2-inch deal planks, and the contact beds are covered with small-mesh galvanized wire-netting to keep off leaves, &c.

It is claimed for this installation that it works automatically, with a modicum of attention, causes no nuisance whatever, and produces an excellent effluent.

An installation for a country house in Surrey is shown in Plate XVI. It was designed by Mr. G. Lister Sutcliffe, the editor of this work, who has furnished the following description:—"The house is normally occupied by about ten persons, and the sewage from a four-stall stable is also treated. The installation consists of a small straining chamber, a covered septic tank holding about one day's flow of sewage and provided with a dipped inlet and outlet, and a percolating filter. The natural fall of the ground was such that the filter was constructed about 6 feet in depth. The bottom of the excavation was covered with concrete, in which channels were formed to collect the effluent. Three sides of the filter were built with large flints excavated on the site, and laid without mortar in order to afford ample aeration for the sewage on passing through the filter. The bottom of the filter was also formed with flints to assist the drainage, and above these crushed and washed coke screened to pass through a $\frac{3}{4}$-inch sieve, and with all fine material screened out by means of a $\frac{1}{4}$-inch sieve, was placed to the required depth. The method of distributing the sewage over the surface of the filter is of the greatest importance, and in this case Farrer's automatic apparatus was adopted. This consists of a triangular trough, or tipper, divided into two parts by a longitudinal diaphragm, and working in bearings at the ends in such a manner that each part of the trough alternately is brought under the outlet from the septic tank. When one part is full of sewage, the tipper overbalances and discharges its contents into a series of perforated iron channels extending over one-half of the filter. At the same time the other part of the tipper begins to receive the sewage from the tank, and when this is full

the tipper overbalances in the opposite direction, and discharges the sewage over the other half of the filter. This arrangement allows the sewage from each half to drain away before the next dose is applied. From the filter the effluent was taken to a small distributing chamber from which three lines of 3-inch agricultural pipes were laid as near the surface of the ground as practicable. Two paddles were provided so that the effluent could be turned into one drain, while the other two were at rest. At the time of writing, the installation has been at

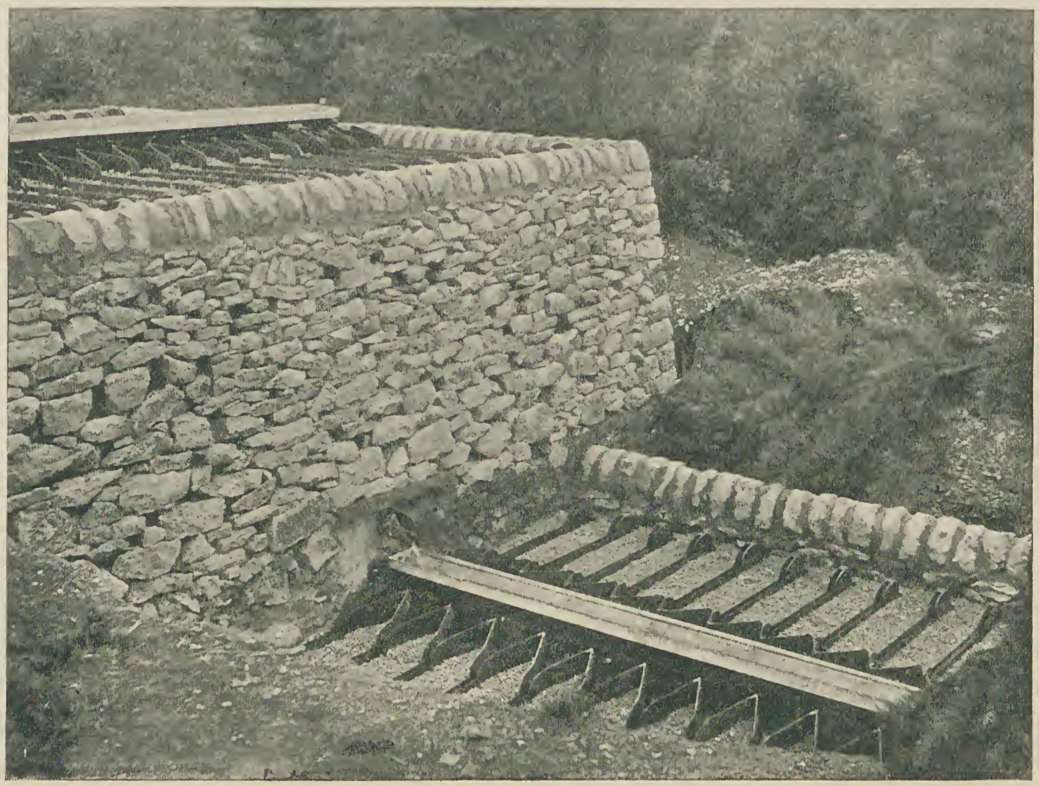


Fig. 434.—Sewage Works, Thornbridge Hall, Derbyshire.

work for more than two years without the slightest nuisance, and during the whole of that period the septic tank has not been cleaned out in any way: the only attention required has been in clearing out the screening chamber, raking over the surface of the filter to remove leaves and weeds, filling the lubricators of the tipper and cleaning it, and altering the position of the paddles in the distributing chamber. A year after the works were constructed, the distributing chamber was replaced by a tank, so that the effluent could be used for watering certain parts of the garden."

The same kind of distributor was adopted by Mr. Sutcliffe in the works

designed by him for treating the sewage at Thornbridge Hall in Derbyshire, but in this case, as the effluent passed into a lake in the park, double filtration was considered necessary. A general view of the two filters is shown in fig. 434. The old septic tank and contact-beds, which had proved an utter failure, were utilized as far as possible, but the septic tank was nearly quadrupled in size as it was originally much too small for the quantity of sewage to be treated. After the new works had been in operation for three months, the effluent was analysed by Messrs. Bostock Hill & Rigby, who reported as follows:—

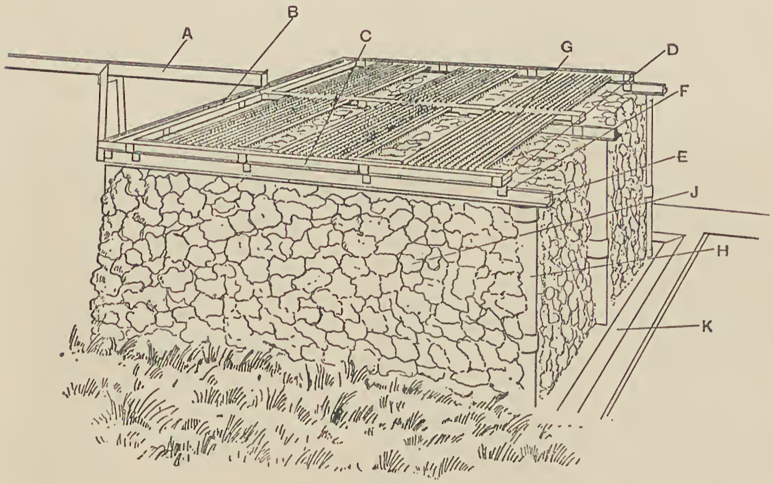


Fig. 435.—The "Stoddart" Sewage-distributor.

Table XXIX.

ANALYSTS' REPORT ON EFFLUENT FROM BACTERIAL SYSTEM WITH DOUBLE FILTRATION

Bostock Hill & Rigby, Public Analysts' Laboratory,
14 Temple Street, Birmingham.

WATER.

Results of Analysis expressed in parts per 100,000.

Description.	Free and Saline Ammonia.	Organic Ammonia.	Chlorine in Chlorides.	Nitrogen in Nitrates and Nitrites.	Total solid matter.
Effluent from Thornbridge Hall, January 28, 1907, from No. 2 filter, ...	0·008	0·032	4·4	0·99	36

February 12, 1907.

REMARKS.

Dear Sir,—The results detailed above show the effluent to be remarkably well purified, and to be clear and free from odour of sewage. It is also non-putrescent, and may be considered a very good sample, quite fit to be turned into the stream.

Yours faithfully,

(Signed) BOSTOCK HILL & RIGBY.

The method of distributing the sewage over the surface of the filter is of the greatest importance. An equal distribution in small quantities or drops is necessary, and this ought to be effected in a simple manner without complicated mechanism. In addition to the distributors already described, many others have been devised, but two of those only can be mentioned which are specially adapted for private installations. The "Stoddart" apparatus (fig. 435) consists of a series of corrugated and perforated sheets, which are laid over the filter, and

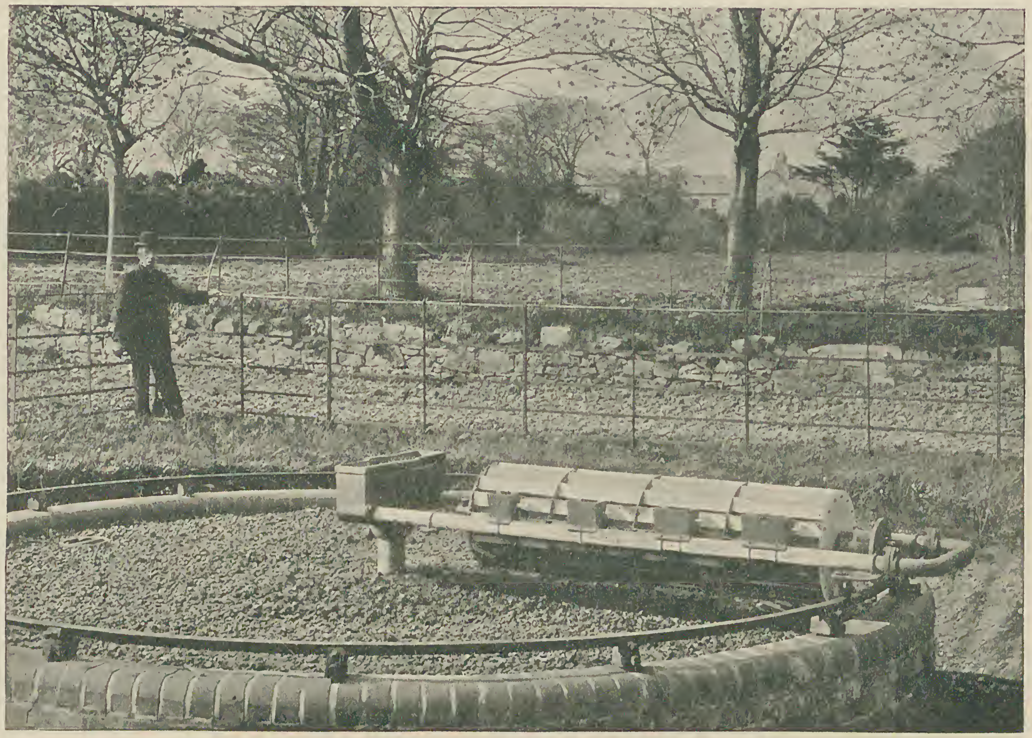


Fig. 436.—The "Fiddian" Sewage-distributor.

allow the sewage to escape in drops through the perforations. The "Fiddian" distributor (fig. 436) is a breast water-wheel operated by about a 15-inch head of sewage. The end of the axle is swivelled on a support in the centre of the circular filter, and the other end is attached to a wheel which moves on a circular track around the filter, as the water-wheel is turned by the sewage.

The design of a system of sewage-purification for a country house or group of buildings is not such a simple matter as the brief descriptions given above might appear to indicate. The position of the tank and filter can as a rule be settled without much difficulty, but in many cases expert knowledge is required to design them in such a way that purification of the sewage will be effected without nuisance. The composition of the sewage may vary within wide limits.

It may be "strong" or "weak" according to the quantity of water with which it is diluted. In some cases the quantity of urine, &c., from stables may be very great in proportion to the domestic part of the sewage. In other cases there may be an excessive amount of grease, and as this is very difficult to treat, its collection in grease-traps may be necessary so that it will not pass to the sewage tank and filter. Even the quality of the water supplied to the buildings affects the purification of the sewage. While, therefore, the quantity of the sewage may be taken as a rough-and-ready guide, the quality must also be taken into consideration, and to ascertain this one or more chemical analyses are often necessary. It may be well to repeat that difficulties will be experienced if surface water and subsoil water are allowed to enter the drains in large quantities; it is best to exclude them altogether. The septic tank itself must be neither too large nor too small, and must be so designed that the contents are not unduly disturbed by the inflow and outflow of sewage. As a general rule, it may be stated that a percolating filter gives better results with domestic sewage than a contact bed, but under certain conditions the latter must be used, and the beds themselves and the apparatus for controlling the filling and emptying must be properly designed to prevent clogging of the apparatus and incomplete discharge of the sewage. In the case of percolating filters, the area and depth of the filters, the nature and size of the bacterial medium, the apparatus for distributing the sewage, and other details, must be carefully considered. The question of single or double filtration must also be answered as the given conditions may direct.

CHAPTER VIII.

INTERCEPTION OR DRY SYSTEMS.

Having thus far treated of methods of dealing with "water-carried" sewage, it will be necessary to turn to the question of what is known as "**interception**", or the intercepting of the fæcal matter and waste products of our dwellings, &c., without allowing them to enter the sewers. It must not, however, be lost sight of that, in every large community, sewers will still be a necessity, even if an "interception" system is introduced, for, as the Rivers Pollution Commission of 1868 reported (*First Report*, vol. i. 1870, p. 30), "the retention of the solid excrements in middens is not . . . attended with any considerable

diminution in the strength of the sewage, although the volume, even in manufacturing towns, is somewhat reduced". In other words, an interception system will not do away with the necessity for sewers to carry off the slop water, the washings of yards, and also of the public streets, percolations of filth from cesspools, dung-pits, and the like, and also manufacturers' wastes, public urinals, &c.

The crowding of our populations into cities, and the altered conditions of our lives, have made it absolutely necessary that the cleanly and convenient method of carrying away our sewage-matters by water should take the place of the filthy method of storing such matters in or near our habitations. The difficulty of removing and ultimately disposing of this filth is a serious objection against all the so-called "**interception**" **systems.** These systems may be summarized as follows:—

(1) Various forms of middens.
(2) Box, tub, or pail closets.
(3) Dry-earth, ash, or charcoal closets.

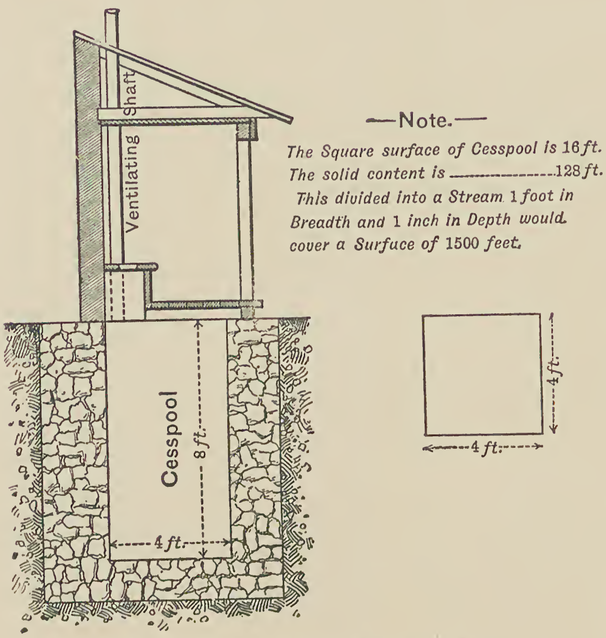


Fig. 437.—Section of Insanitary Privy and Cesspool.

The primitive "fosse", ditch, or simple hole dug into the ground to receive the human fæces gradually evolved into **the privy,** no doubt first by the introduction of some kind of rough seat, and then it was built round and roofed for privacy (hence "privy") and for shelter. Before this advance was made, it is probable that the fosse or hole was lined, or "steined" as it is technically called, with a rough lining of stones or bricks. Then a more modern seat was added, and the privy or midden was complete (fig. 437).

Fortunately the old-fashioned midden-closet is now almost a thing of the past in most of the larger towns in this country, though it is still to be found in rural districts and attached to isolated houses. Mr. Redgrave, in a paper which he read before the Institution of Civil Engineers in 1876,[1] said:

"It can only be spoken of in the language of Mr. Radcliffe (*vide* Rivers

[1] Vide *Minutes of Proceedings of the Institution of Civil Engineers*, vol. xlv. p. 130.

Pollution Commission, 1868, First Report, vol. i. 1870, p. 30) as the standard of all that is utterly wrong, constructed as it is of porous materials, and permitting free soakage of filth into the surrounding soil, capable of containing the entire dejections from a house, or from a block of houses, for months and even years uncovered and open to the rain, the wind, and the sun, difficult of access for cleansing purposes, and unventilated and undrained." And again, in the First Report of the Rivers Pollution Commission, speaking of Manchester, at pages 23 and 24, the commissioners said:—"In spite of district inspection under an energetic and experienced chief, in spite of police assistance, and notwithstanding that the penny post enables every householder so easily to give notice to the scavenger, privies and ashpits are continually to be seen full to overflowing and as filthy as can be. . . . These middens are cleaned out whenever notice is given that they need it, probably once half-yearly on an average, by a staff of night-men with their attendant carts. Occasionally twenty or thirty middens are thus cleaned out in succession, the contents being wheeled along the whole length of the row, making the air offensive for several nights together, and creating a nuisance none the less injurious because, the work being done when the people are asleep, the filthy smell is not perceived." It is almost unnecessary to state that a privy of this description (see fig. 437) is thoroughly insanitary, when it is situated near any dwelling-house.

Later sanitation insists that where **these abominations** exist, the pit shall be lined imperviously—to prevent soakage into the surrounding soil—with hard bricks or stones, set in cement mortar, and rendered or covered with cement mortar or other hard impervious material. Sanitation also insists that the midden shall be so covered and ventilated that the effluvium may pass away harmlessly into the air, and not solely through the seat into the privy building. The pit should also if possible be drained, so as to carry off the moisture, and the shape of the pit should be so arranged that its contents can be easily removed, and with as little nuisance as possible. A still more modern improvement is the provision of some simple arrangement whereby the contents of the pit may be deodorized by the addition of dry earth, ashes, or some such cheap absorbent and deodorant.

It will be seen on reference to fig. 437 how difficult it would be to cleanse such a privy or midden, but the following illustration shows an example of an **improved midden-privy** as constructed at Nottingham. The bottom of the receptacle is concave, in order that everything may gravitate towards the centre of the pit, and the brickwork is well rendered in cement on

the inside to make the pit impervious. There is also a special opening through which ashes or other deodorant may be thrown on to the contents of the pit, and a ventilating shaft is also shown to be carried up, so as to give thorough

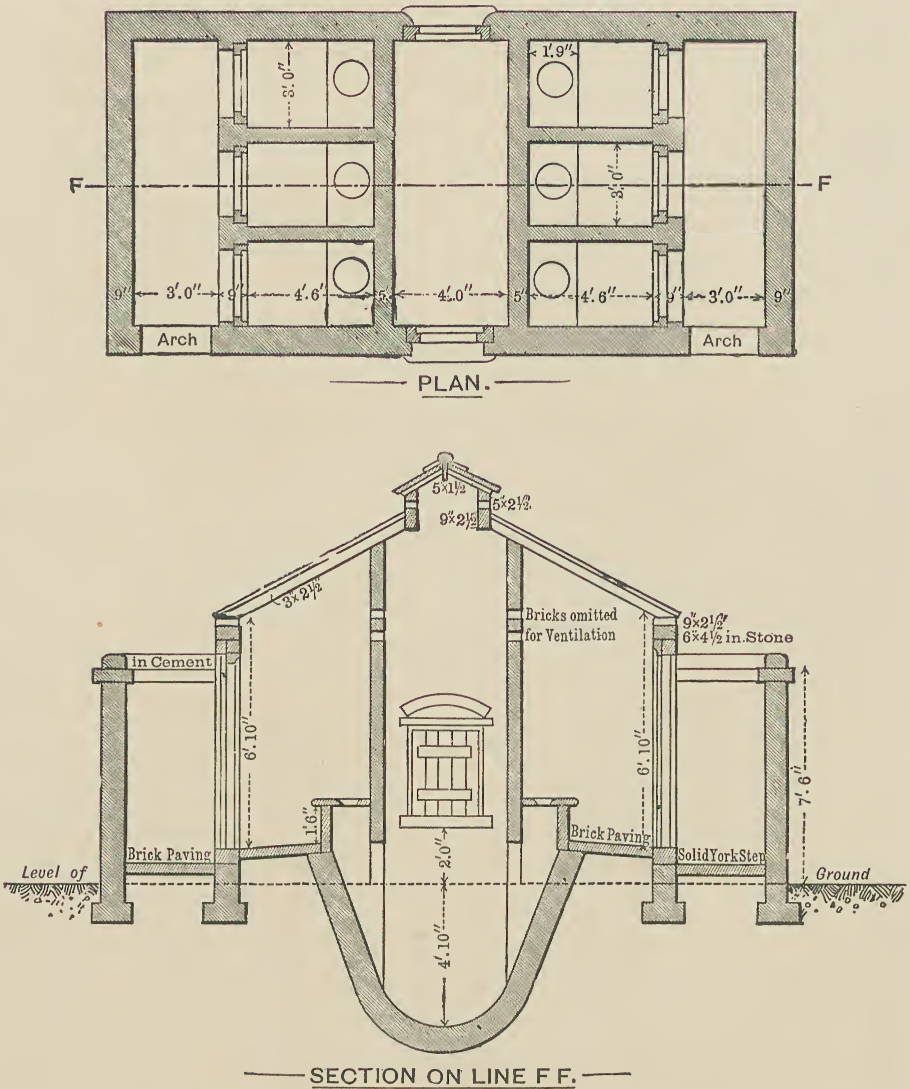


Fig. 438.—Plan and Section of Midden-closet in use at Nottingham.

and safe ventilation. The riser of the seat is constructed in brickwork, and the floor is paved.

The Nottingham type of midden (fig. 438) is free from many of the objections raised against the old-fashioned midden-privy; but a better example is that of **the Burnley midden-closet** (fig. 439), the receptacle of which has the floor constructed of glazed stoneware, with an overflow-pipe connected with

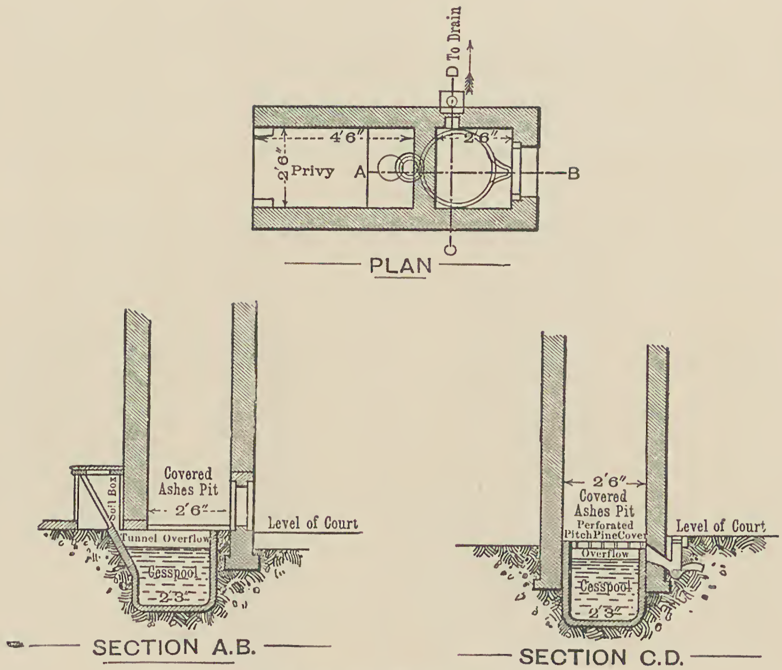


Fig. 439.—Plan and Sections of Midden-closet in use in Burnley

the sewer, and is of such small dimensions that its contents can be easily and readily removed.

A further improvement is shown in **the midden-closet as formerly constructed at Stamford** (fig. 440), where the seat is hinged, so that it can be thrown up

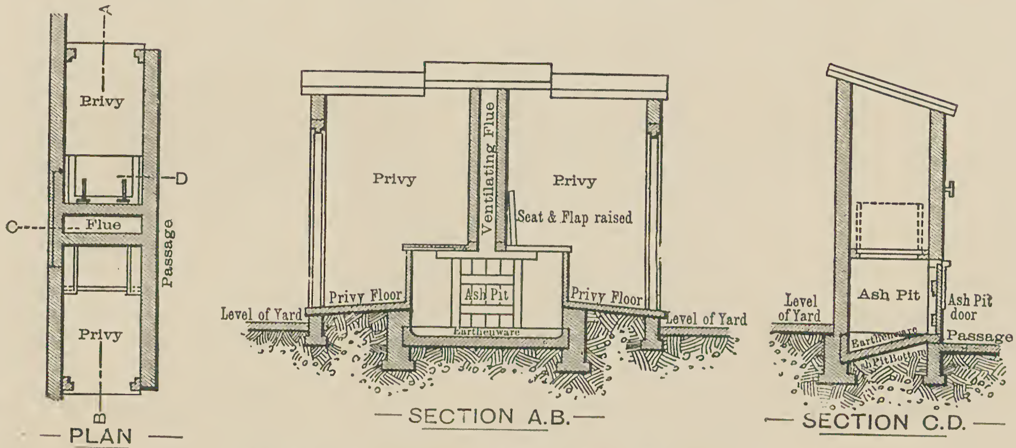


Fig. 440.—Plan and Sections of Midden-closet in use in Stamford.

and the house-ashes emptied on to the contents, as these assist in deodorizing the fæcal and other putrescent matters. The midden is also very shallow, necessitating frequent cleansing.

The final type of midden-privy which will be given, is that which has been suggested by **the Board of Education** in connection with schools where "neither water closets nor earth closets are practicable". It is shown in fig. 441. Two plans are given, the upper showing the door at one end and the lower showing

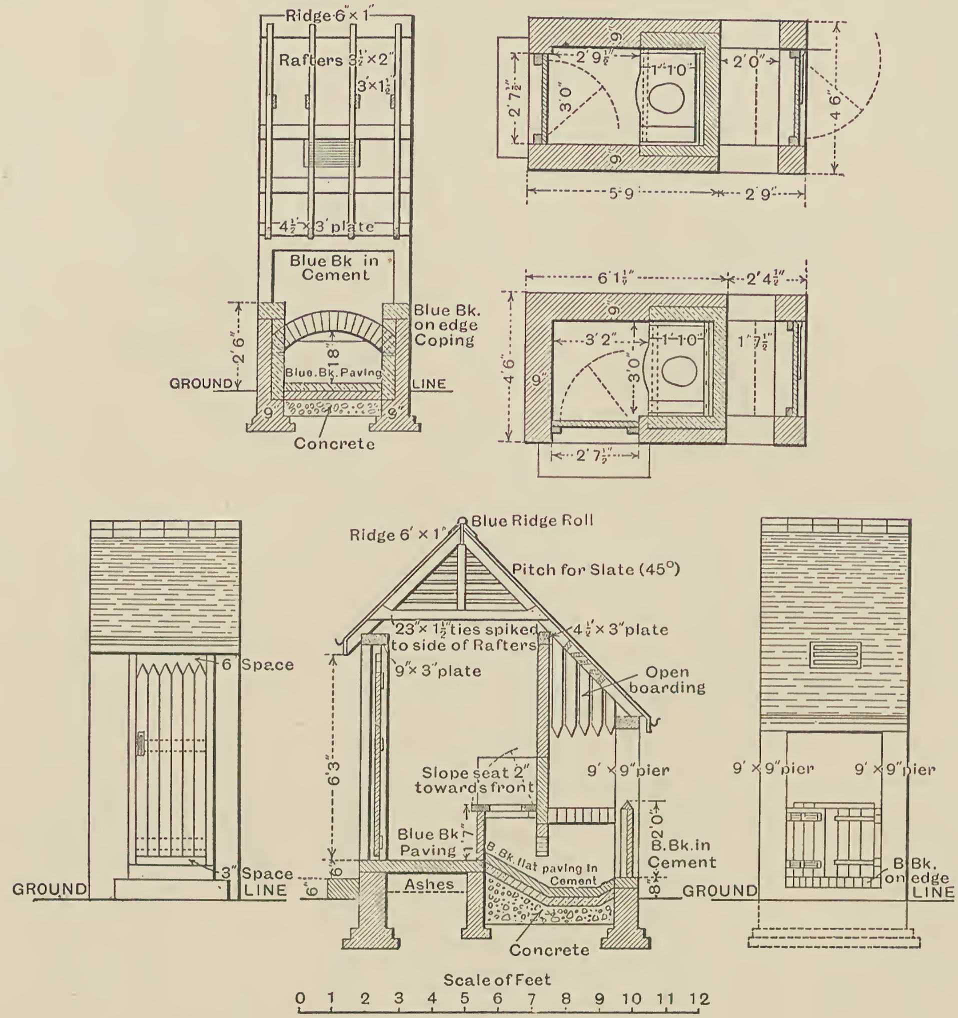


Fig. 441.—Privy recommended by the Board of Education.

it at the side. The front elevation and the longitudinal section show the door at one end, but the other elevation and section apply to either of the two plans. The special features are that the bottom of the receptacle is 3 inches above the ground, blue bricks are used for the walls and pavings likely to be contaminated, and provision is made for the circulation of air through and around the building. It will be seen that the gable ends are fitted with louvre ventilators, and that

open spaces are provided above and below the door. The pit is also thoroughly ventilated, while at the same time rain is almost entirely excluded.

Thus, the midden or privy pit became smaller and smaller, and its transition into **the pail or receptacle closet** was an easy step. This is now known as the "Tub", "Pan", or "Pail" Closet, and is largely used in one form or the other in many manufacturing centres. It is undoubtedly a great improvement on midden-closets, as, on account of the small size of the receptacle, the fæces

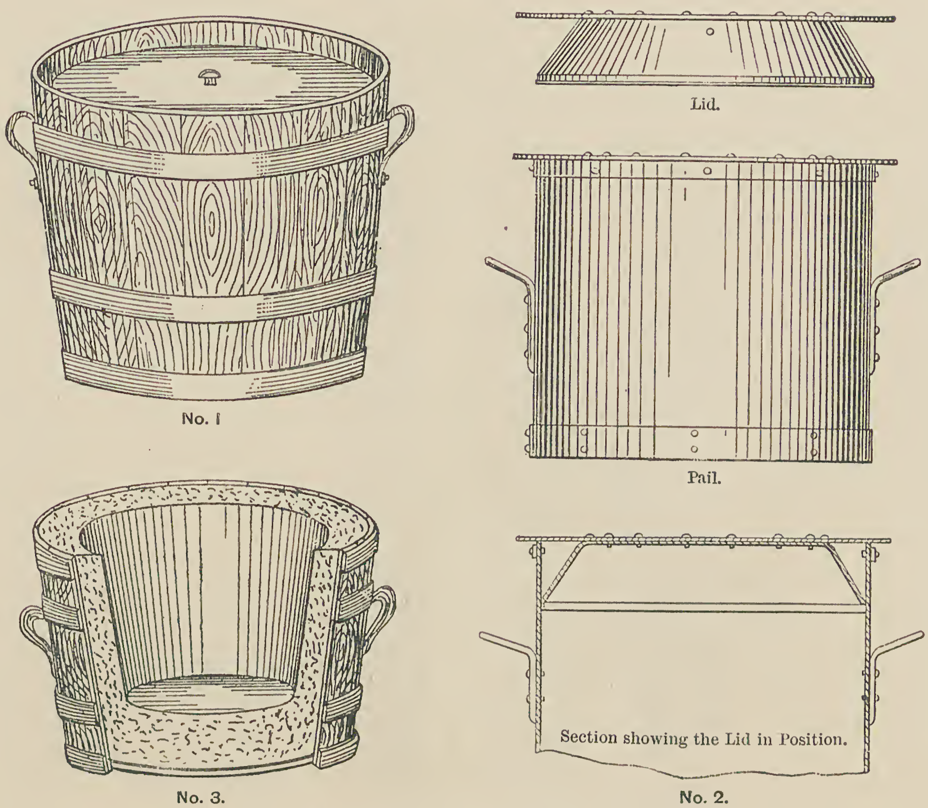


Fig. 442.—Excrement-pails and Covers.

are more frequently removed, and the labour and nuisance of such removal are greatly reduced. Each closet must have its own receptacle, and the front of the seat must be arranged to take out, so that the pail can be easily removed. The pail used at Rochdale is wood (No. 1, fig. 442), while the Birmingham pail and cover (No. 2) are of galvanized iron. The covers are provided to prevent the contents splashing out when the full pails are being carted to the depot.

Manchester was one of the first cities to alter privies into pail-closets, and **to add the ashes to the fæcal matter** as shown in fig. 443. It will be observed that the building in this case is somewhat similar to a common privy, but that

underneath the seat is an iron pail, circular in form, which contains the fæces, &c., and the garbage and other matters which the woman is seen to be emptying into a series of screens or sifters, arranged in a shaft or long box outside the wall of the privy. The finer ashes are sifted out and fall into the pail under the seat, whilst the larger cinders fall down into the box below, from which they can be easily removed by means of a door, and re-burned or used in other ways. There

Fig. 443.—View of Manchester Pail-closet with Cinder-sifter.

are several modifications of this process, by which the fine ash is added to the contents of the pail, all being undoubtedly a great advance upon the old privy or midden.

Not long after the introduction of the pail-system into this country, Mr. Goux of Rochdale introduced **an absorbent pail,** in which the ashes are supplied to the pail before it is sent out, the sides and bottom being lined with ashes pressed into shape by means of a mould, as shown in No. 3, fig. 442. In addition to ashes, the absorbing material contains dry street-sweepings and

factory-waste, to which is added sulphate of lime; the mixture is pressed down, and when the pail is placed in the closet, the mould is withdrawn. It is claimed that the absorbent material takes up the urine and other moisture, prevents decomposition, and facilitates the conversion of the excreta into a portable manure. The opponents of this special pail say that there is nothing in these claims, and that the lining merely adds to the weight of the pail. There can be no doubt, however, that the attempt, whether successful or not, merits approbation.

The collection of the pails is in most cases effected by means of specially-constructed closed wagons, which are sent round, generally at night, accompanied by men, who collect the full pails and substitute empty ones which have been previously cleansed and disinfected at the various depots.

The contents of the pails are variously treated. In some cases they are mixed with a sufficient quantity of dry ashes (house-refuse) to absorb the liquid, and are then placed in a stirring-mill, where offal or other animal refuse is added. Whilst this mixture is passing through the mill, about 5 per cent of gypsum (sulphate of lime) is added to fix the ammonia. The mixture thus prepared consists approximately of about 20 per cent of excreta and urine, 20 per cent of offal, &c., 5 per cent of gypsum or sulphate of lime, and 55 per cent of fine ashes. This is then passed over a fine sieve or screen, which takes out all the coarse parts, and the residuum is put into bags and sold as manure, which is said to be worth about 15 shillings a ton.

The following is a description of **the method at one time followed at Manchester.** The pails having been emptied over a grating which held back the solid matter, the liquid contents were evaporated to one-tenth of the original bulk, or even less, in an apparatus called the "concretor", which consisted of a revolving cylinder, 8 feet long and 4 feet 6 inches in diameter, having its ends partially closed by annular rings, and fitted inside with scroll-like plates of thin metal. The liquid was admitted into this cylinder, and as it revolved, these scroll-like surfaces became wetted; the evaporation was effected by passing heated gases through the cylinder. As these came into contact with the wetted surfaces of the metal scrolls, rapid surface-evaporation took place, the temperature of the liquid, however, remaining low,—so low that, though it was discharged from the cylinder at nearly the consistency of treacle, it was rarely, if ever, at so high a temperature as 130° F.

The hot gases, used for effecting evaporation in the concretor, resulted from the combustion of refuse-material, usually consisting of a small portion of cinders and a large quantity of ashes, together with animal, vegetable, and mineral

refuse, forming a compound containing too little manure to be valuable, but quite enough to be objectionable. This material, so difficult to be disposed of satisfactorily, and often saturated with water, was shot into a furnace of special construction termed the "Destructor", so arranged that the material had to traverse a considerable distance within it, exposed to the products of combustion on their way to the chimney, and to the heat radiated from the roof and sides, before it reached the fire-grate. It was thus effectually dried before any attempt was made to burn it. The products of combustion from this furnace were passed through the "concretor" cylinder to effect the evaporation required there on their way to the chimney. The gases, resulting from the combustion of the materials above described, usually contained a small quantity of sulphurous acid, which was sufficient to slightly acidify the liquid in the concretor. If they did not contain it naturally, a little sulphur was added for the purpose of producing the acid.

The low temperature was not sufficient to cause any appreciable loss of nitrogen, or evolution of ammonia, from the slightly-acidified liquid undergoing concentration. The concentrated material was therefore a fairly strong manure. A random sample of it had been reported upon by Messrs. Burghardt, Grimshaw, & Co., Dalton Laboratory, Manchester, as "undoubtedly a very strong manure, owing especially to the high amount of available nitrogen which decomposes in the ground, and may be expressed as 9·88 per cent of ammonia".

Refuse fuel, such as that used in the "destructor", produced a large amount of clinker, which, when ground up with a little lime, formed a strong mortar. The process of concentration was not a source of nuisance. "Even the most offensive putrid urine speedily lost almost the whole of its disagreeable odour when undergoing concentration, doubtless owing to the action of the sulphurous acid upon it."

The pails themselves had a little charcoal put into them to deodorize their contents, and render them innocuous, and charcoal might in like manner be added to the concentrated liquid to prevent it from becoming offensive. This charcoal was also manufactured from refuse material; it was composed of carbonized street-sweepings, market-refuse, &c., and needed special apparatus to carbonize it, since the low value did not permit of costly handling, while it was bulky and difficult to separate. The heating was effected by a small furnace fed with cinders and other refuse fuel, while the carbonizing kiln consisted of a rectangular chamber of considerable height, into the top of which the material to be operated upon was thrown, and through which it gradually descended as its bulk diminished and the material below was removed.

Finally, when sufficiently carbonized, it was withdrawn through a slide in the bottom of the chamber. The fire in the furnace was kept thick, and the supply of air to it small, so as to prevent the admission of sufficient oxygen for perfect combustion; thus the products of combustion from it could only heat, and not burn, the materials with which they came into contact, and they might therefore safely be brought into direct contact with the materials to be carbonized. These products of combustion entered the kiln, or carbonizing chamber, near the bottom, and were guided around it by iron plates which touched the wall at their top edges, but sloped so that their bottom edges were some distance from it. These ran around the chamber in a spiral form, and kept open a passage, along which the products of combustion could always find a way to the chimney, while, as they were open at the bottom, the gases could come into direct contact with the materials in the kilns. The plates becoming heated also helped to dry and carbonize the materials. Finally, the products of combustion were led away to the chimney through a flue near the top of the chamber.

By the above methods, almost the whole of the material which came into the yard was effectually dealt with, and turned into a product of much less bulk, capable of being applied to some useful purpose either as a manure, a deodorant and disinfectant, or as mortar, while there was no need for costly chemicals or extraneous fuel. At the same time, the whole of the matter was rendered harmless, and incapable of spreading infection or disease, for it was purified by fire.

Another apparatus for the disposal of the contents of pails consists of a **steam-jacketed cylinder** about 13 feet long and 4 feet in diameter, fixed on a hollow revolving shaft, with hollow agitators into which steam is admitted at 60 lbs. pressure. The contents of the pails, mixed with about 1·25 per cent of sulphuric acid, are placed in the cylinder, and the agitators, filled with steam, slowly revolve. About $2\frac{1}{2}$ tons of pail-contents, holding at least 83 per cent of water, are reduced in $3\frac{1}{2}$ hours to about 4 cwts. of a lumpy dark-red loam, containing only about 5 per cent of water. This is allowed to cool, and then riddled into a powder, which is sold as manure, in some cases being of a value of £6 or £7 per ton. Its chemical analysis is given in the following table:—

Insoluble silica, ...	=	3·216 per cent.
Lime, ...	=	1·310 ,,
Oxide of iron and alumina, ...	=	0·607 ,,
Sulphuric acid, ...	=	1·885 ,,
Phosphoric acid, ...	=	3·102 ,,
Sulphate of potash, ...	=	5·586 ,,

Chloride of magnesium, ...	=	1·910	per cent.
Chloride of sodium, ...	=	5·120	,,
Sulphate of ammonia, ...	=	22·191	,,
Organic matter, ...	=	55·073	,,
Total, ...	=	100·000	

With regard to the dry-earth or pail systems, there can but be one opinion as to their unsuitability for use in towns, and we must agree with the following **conclusions of the committee appointed by the Local Government Board** in 1875 to enquire into the various methods of sewage-disposal:—" That the retention . . . . of refuse and excreta . . . in cesspools . . . or other places in the midst of towns, must be utterly condemned, and that none of the (so-called) dry-earth or pail systems or improved privies can be approved other than as palliatives for cesspit middens".

The committee appointed by the Society of Arts in 1876, to enquire into various subjects connected with the health of towns, came to the following resolutions:—

" (1) That the pail-system, under proper regulations for early and frequent removal, is greatly superior to all privies, cesspools, ashpits, and middens, and possesses manifold advantages in regard to health and cleanliness, whilst its results in economy and facility of utilization often compare favourably with those of water-carried sewage.

" (2) That hitherto no mode of utilizing the excreta has been brought into operation which repays the cost of collection.

" (3) That the almost universal practice of mixing ashes with the pail-products, though it applies there as a convenient absorbent and possibly to some extent as a deodorant, is injurious to the value of the excreta as a manure.

" (4) That for use within the house no system has been found in practice to take the place of the water-closet."

The earth-closet is too well known to demand much description. It was the invention of a clergyman, the Rev. J. M. Moule, and has been in operation for a great number of years. It consists of an ordinary closet-seat, under which is a metal container into which is dropped, either automatically or by means of levers, &c., attached to the seat, or by a scoop, a certain quantity of dry earth, which absorbs the moisture and deodorizes the fæcal matter.

The building in which such a closet is fixed should not be inside the house, but should be a separate building, or approached by a short passage with cross ventilation. It must be well lighted and ventilated, with an impervious floor of asphalt, cement, or tiles. The container beneath the seat should be con-

structed of galvanized iron, and should fit into guides so as to be always directly under the seat. It should be removable either at the back or front, and not contain more than about two and a half cubic feet, so as to ensure constant removal. The contents of the container can be used, with great advantage and perfect safety, in the garden attached to the house, however small.

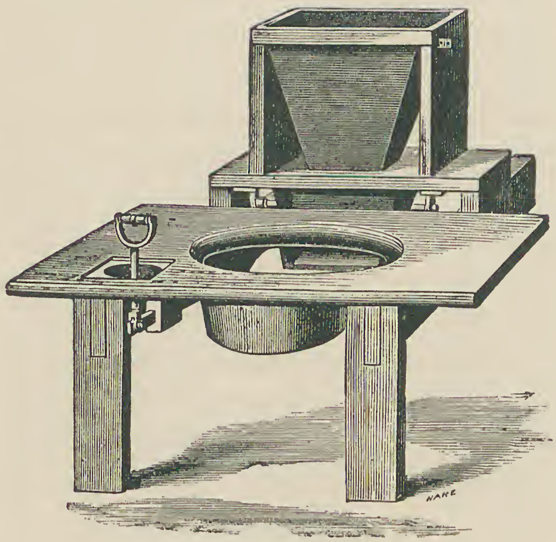


Fig. 444.—View of Moule's Earth-closet, with Pail removed.

Dr. George Vivian Poore, in an excellent book, *Essays on Rural Hygiene*, gives some good advice and practical remarks upon this subject. He says: "In order that the dwelling and its surroundings may be wholesome, it is essential that all excremental and putrescible refuse be removed *every day.* To allow such stuff to accumulate for a week before removal, as is done in some places where what is known as the 'pail system' is in vogue, is quite indefensible, and I believe that a daily removal would be found easier of accomplishment than a weekly removal." He considers that the collected material should be at once buried, and as the material when once put under ground is safe, it might be shallowly buried close to the house and the ground cultivated. "If applied with care and knowledge, it can do nothing but good." No antiseptic must be mixed with it, as of course such admixture would kill

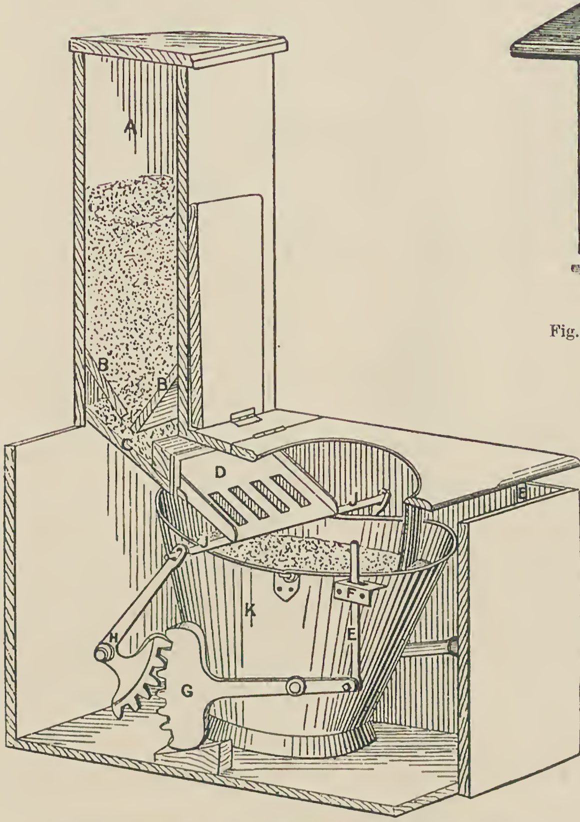


Fig. 445.—Sectional View of the British Sanitary Company's Self-acting Earth-closet.

its fertilizing properties and render the ground sterile, besides killing the microbes which Nature has provided to do the work of purifying.

Earth-closets are now made either to be operated by a handle, as shown in fig. 444, or to be "self-acting", the motive power in the latter case being furnished by the weight of the person using the closet. **A self-acting earth-closet** of this kind is shown in fig. 445. A reference to the illustration will explain the nature and working of this closet. A is a magazine for containing the dry earth, or other deodorizing material used. B and B′ are the sustaining pieces, which bear up the weight of the material, and also form the regulating orifice. C is a bevelled shelf, which is lined with a metallic plate, and carries

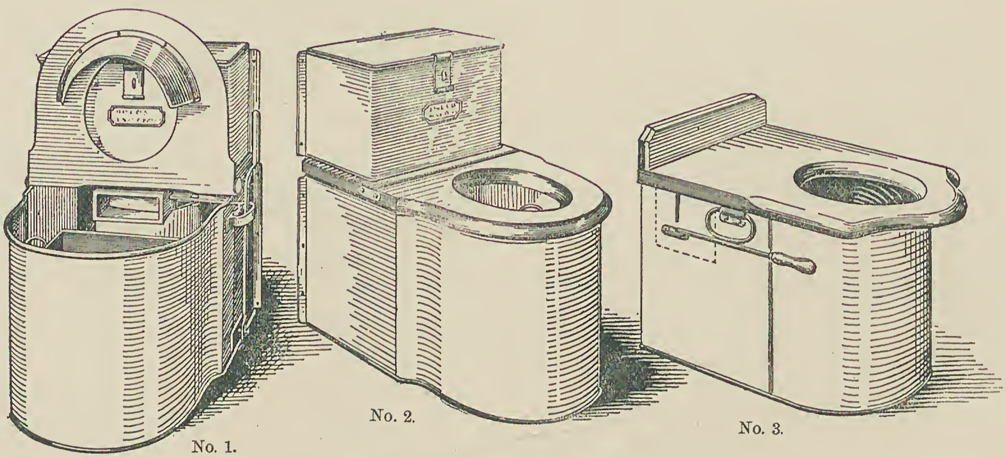


Fig. 446.—Adams's Earth-closets.

in front an iron frame or mouthpiece, through which the perforated shovel or spreader D travels. The action is communicated as follows:—When the closet is being used, the seat is depressed about an inch, forcing down the rods E E on each side of the seat, which raise the long and weighted end of the segmental toothed levers G, which in turn throw back the long end of the lever H. This *duplex action* is coupled by the cross bar J, to which is attached the shovel D. This is then withdrawn to the back of the bevelled shelf C, and receives the charge of earth, &c. When the seat is relieved, the weight of the lever brings out the shovel quickly, thus spreading the earth, &c., over the excreta.

Two other varieties of earth-closet are shown in fig. 446. Nos. 1 and 2 represent the "Domestic" closet, which is made of sheet-steel, either painted or galvanized. The container for the dry earth or other deodorant is at the back of the seat, and is operated by the lever handle shown in No. 1. An

automatic device can be fitted to the closet instead of the lever handle. The pail can be lifted out after raising the seat, or can be removed through an opening in the back wall of the building. The "Miniature" earth-closet (No. 3) has a container of sheet-steel, either painted or galvanized, and the dry-earth box is placed in the upper part of the container under the back of the seat. A handle is provided for discharging the earth. There is no separate pail in this closet, but the container itself forms the receptacle for fæces. The seat can be easily taken off, and the container can then be carried away to be emptied. This is a simple arrangement. As the container and earth-box are small, the apparatus must be emptied at short intervals, and this is an advantage from the sanitary point of view. In some earth-closets, made by the same firm, the container is of glazed stoneware.

Cinder-sifters are made for screening out the coarse parts of domestic ashes. The fine dust thus obtained is well adapted for use in earth-closets.

NOTE ON THE LEGAL INTERPRETATION OF THE WORDS "DRAIN" AND "SEWER".

BY

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NOTE ON THE LEGAL INTERPRETATION OF THE WORDS "DRAIN" AND "SEWER".

According to the Public Health Acts Amendment Act, 1890, Section 19 (1):— "Where two or more houses belonging to different owners are connected with a public sewer by a single private drain, an application may be made under section 41 of the Public Health Act, 1875 (relating to complaints as to nuisances from drains), and the Council may recover any expenses incurred by them in executing any work under the powers conferred on them by that section from the owners of the houses in such shares and proportions as shall be settled by the surveyor, or (in case of dispute) by a court of summary jurisdiction"; and Section 19 (3) provides that "for the purposes of this section, the expression 'drain' includes a drain used for the drainage of more than one building".

Mr. M'Morran's note to this sub-section is as follows:—

"The provisions of sub-section (1) and of this sub-section make the word 'drain' applicable to a drain which receives the drainage of two or more houses belonging to different owners. Such a drain would formerly have been a sewer, and as such vested in and repairable by the local authority, and there was not such a thing as a single private drain of this kind if the word private means not vested in the local authority."

It will be noticed that for the first time we have, in this section, any statutory recognition of public sewer and private drain.

The most noted decision is Travis *v.* Uttley. A drain passing under three houses at Halifax was held to be a public sewer by the Court of Appeal, on 4th December, 1893 (L.R., 1894, and Q.B.D., p. 233). Since that date it has transpired that the Public Health Acts Amendment Act, 1890, had not at that time been adopted in Halifax. At Hove, an owner, relying on this case, did the work, and in the County Court secured a judgment against the Commissioners, who appealed, and succeeded in getting the judgment reversed (see Self *v.* Hove Commissioners, Q.B.D., 685, 25th January, 1895); Justices Wills and Wright decided that the Commissioners were not liable for the cost incurred in recon-

structing a drain which it was discovered drained a house adjoining that in respect of which a notice had been served, and further held that the Commissioners having adopted Part III of the Public Health Acts Amendment Act, 1890, the drain was not a sewer, and therefore not repairable by them, and consequently their notice did not amount to a request to the plaintiff to do the work.

This decision was, a few weeks later in the same court, April 3, by the Carlisle case, Hill *v.* Hair (Q.B.D., 906), considerably limited. The respondent was the owner of one of several houses erected before the passing of the Public Health Act of 1848. The Corporation had adopted Part III of the Public Health Acts Amendment Act, 1890, and their Improvement Act of 1887 contains a section (134) somewhat similar to section 19 of that Act, with the omission of the words "belonging to different owners". The combined drain being defective, the Council proceeded against the respondent by summons, which, however, was dismissed by the magistrates on the ground that the drain was a sewer vested in, and repairable by, the authority, and the High Court upheld this decision. This judgment seems to imply that section 19 of the 1890 Act does not apply to drains which were already public sewers at the passing of the Act of 1890, and this combined drain having already become a sewer vested in the local authority by virtue of the Public Health Act of 1848, could not possibly be a single private drain "within the meaning of the later Act".

In 1897, in the case of Seal *v.* Merthyr Tydfil Urban District Council, the Court of Queen's Bench came to an entirely different decision, and an interpretation was given of the words "private drain" which is more in accord with what was generally understood to be the meaning of the words until the Halifax case was decided. It is important to compare this Merthyr case with the previous ones quoted. The particulars are as follows:—The case of Seal *v.* Merthyr Tydfil Urban District Council, tried in the Queen's Bench Division before Justices Cave and Ridley, was a case stated by the Justices of the Peace for the County of Glamorgan, sitting at Merthyr Tydfil in January of 1897. Upon the complaint of the Merthyr Tydfil Urban District Council, the appellant (Seal) was summoned for that he being the owner of certain premises Nos. 23, 30, 31, 32, 33, 34, 35, 36, 38 Cromwell Street, allowed a nuisance to exist thereon. The proceedings were taken under section 41 of the Public Health Act, 1875, as extended by section 19 of the Public Health Acts Amendment Act, 1890. A large number of houses had been erected by the Tydfil Well Building Club (of which appellant was the secretary and receiver of rents) upon both sides of a new street called Cromwell Street. The houses on the south side were numbered 21 to 40. A

drain was made by the Club running at the back of the houses through the gardens, and this drain joined the sewer of the District Council. A connection from each house with the drain at the back was made by a branch drain from the water closets and slop sink gullies. The drain commenced at the Council's sewer, and was laid at the back of the houses as far as No. 40, and could not be used by other premises. The Council had adopted the Public Health Acts Amendment Act, 1890. Upon the evidence the justices found as facts:—That the appellant was the owner within the meaning of the Public Health Acts; that the drain was a drain used by two or more houses belonging to different owners; that it was a drain for the particular houses Nos. 21 to 40 in Cromwell Street and for no other premises, and that it was not a general drain into which any houses could be drained; and that the drain was a nuisance and injurious to health. The respondents contended that the drain running at the back of these houses was a private drain under the definition in sub-section 3 of section 19 of the Act of 1890, and that this drain was a nuisance and injurious to health, and that therefore under section 41 of the Act of 1875 the appellant must abate the nuisance. The Court, without calling upon the respondents, upheld the decision of the justices and dismissed the appeal. Justice Cave, in delivering judgment, said:—"This is a very clear case. By the Public Health Acts, 1848 and 1875, a sewer was defined to be a drain used for the drainage of one building only, and it was found that within the language of the Act of 1875 a drain draining two or more buildings became a sewer, and consequently as such became vested in the local authority. This was found to create the difficulty that if a person built two or more houses on his own land, and drained by a drain, such drain became a sewer, and the liability to repair the same was thrown on the local authority. This difficulty was got over by holding that it did not apply to a drain draining houses within the same curtilage, but that such drain, until it came out into public property, was a drain only and not a sewer. Then came another difficulty, namely, where houses belonging to different owners were drained into the same drain by which they were connected with a public sewer. To meet this difficulty section 19 of the Act of 1890 was passed, which enacted that 'where two or more houses belonging to different owners are connected with a public sewer by a single private drain', then section 41 of the Act of 1875 may be put in force; and sub-section 3 says that 'for the purposes of this section drain includes a drain used for the drainage of more than one building'. What is a 'private drain' within the meaning of the section? It appears to me to apply to a drain constructed on private premises to which the public have not access. Private is to be taken in that sense, that is, as being a drain which

is private and constructed on private land—on land which is not open to the public. I think so far as Hill *v.* Hair is concerned the law was wrongly applied there, the substantial distinction being that of a private drain kept up by a person for his own profit. . . . I think the justices were quite right in their decision, as they found as a fact that the drain was a drain for those particular houses and for no other premises."

SECTION IX.—WARMING

BY

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SECTION IX.—WARMING.

CHAPTER I.

INTRODUCTORY.

The subject of warming is one of the most important in the design of a dwelling-house, and the problem as to the best method to be employed in any particular instance, is not always easy of solution. Warming is so closely allied with ventilation that it will be impossible to avoid repeated mention of the latter subject, but fuller information thereon will be found in a subsequent section, written by another author.

So long as **the temperature of the external air** is above 60° Fahr., no system of warming will be found necessary in the British Isles, except in the cases of rooms or buildings occupied by invalids, where possibly a rise of a few degrees may be deemed desirable. When, however, the external temperature falls below 60° Fahr., some means of warming is desirable; and of course when the external temperature falls much below that point, it becomes essential to raise the temperature of the interior of the building, if the comfort of the inhabitants is to be obtained. Opinions vary in different countries as to the most desirable temperature for the interior of buildings; for instance, in the United States the internal temperature is often kept as high as 70° or even 75° F. Most Englishmen consider these temperatures too high for comfort, and it is generally agreed that a temperature of 60° F. is advisable in living-rooms, and about 55° F. in corridors. The temperature, however, should be kept constant, as directly fluctuations occur, there is a tendency to the production of draughts. In our climate, it is necessary to provide for raising the temperature of the interior of the building uniformly to 60° Fahr., when the external temperature is 25° Fahr. Even in the severest winter, the thermometer rarely falls below that degree of cold; and when it does, the apparatus, if properly designed, can be overworked to the small extent necessary.

The methods adopted and considered desirable in different countries vary so

greatly, both from the great differences in the range of temperature and from the prejudices of the various peoples, that I have thought it best to consider the question of warming in its restricted application to dwelling-houses in the United Kingdom, and in countries having approximately the same climatic conditions. Again, the dwelling-house may be considered under two different aspects: *firstly*, the ideal house which one would desire to have built and to occupy personally; and *secondly*, the house provided by the speculative builder, and bought, leased, or hired by the tenant. At the first glance, there may seem to be little difference between the two classes of houses so far as warming is concerned, but there is this essential distinction: if a house be specially designed by a capable architect, for a client who requires the building to be provided with a suitable system of warming and ventilation,—for the two points must be considered at the same time,—then the design may be arranged so as to obtain the most efficient system, so far as that particular house and local circumstances are concerned. Whereas in the other case, the system which can be applied is at best a makeshift and an addition, for it can rarely be said that the problem of warming receives very special attention from the speculative builder.

The systems in use may be divided into two groups: *firstly*, those in which the warming is produced from a number of separate and distinct heating-centres, such, for instance, as open fires; and *secondly*, systems in which the whole of the house is, or may be, warmed from a central source, which distributes the warmth over the building. I shall endeavour to point out the special advantages and disadvantages of the two systems, although in many cases it will be found desirable to use both systems jointly in the same building.

The chief requirements of a good system of warming are the following:—

(*a*) The apparatus should produce and keep up an equable warmth all over the building, or, at least, an equable warmth over every part of a given apartment.

(*b*) The apparatus should not vitiate the air in any way; that is to say, it should not give off objectionable fumes, smell, or gases, which can enter the apartment.

(*c*) The apparatus should not lessen the humidity of the air; that is to say, the humidity of the internal air should be such as would be found in external air, at the temperature of 60° F., on a still morning in spring.

(*d*) The apparatus should not require skilled attention, or be likely to explode, or to cause damage to property, even if somewhat carelessly handled.

(*e*) The apparatus should be of such a nature as to tend to promote ventilation, and in doing so should not impair the incoming air for breathing purposes.

In discussing the advantages and disadvantages of the various systems, the value of each will be assessed by the way in which it fulfils the above requirements.

In some kinds of warming-apparatus, provision is made for allowing the external air to enter through the apparatus, so that they provide ample ventilation and also warmth at the same time. In view of this, it may be desirable to glance at the **experimental data** which have been obtained. Some persons are much more sensitive to draughts than others, but the conclusions deduced by Sir Douglas Galton and others, from experiments, may be accepted, namely, that a current of air having a velocity of 3 feet per second causes no inconvenience, while a current with a velocity of 5 feet per second is objectionable, and one with a velocity of 10 feet per second is felt as a strong draught. A good deal of discussion has taken place from time to time as to the number of times per hour that the air in a room should be changed, and opinions have differed greatly. It is usually conceded that from 1500 to 1800 cubic feet of fresh air should be provided per hour per person, in order that the ventilation may be perfect; if the lower figure be taken, and a velocity of 3 feet per second be allowed to the incoming air, it is obvious that the area of the inlet must not be less than about 20 square inches per person. If this orifice be arranged so that the incoming air passes over or through the heating-apparatus, then the surface of the latter must be so calculated as to enable it to warm the volume of air to the required temperature.

CHAPTER II.

OPEN FIRES AND STOVES.

The open fire was the earliest method of warming houses, and many persons still consider it by far the best. In early times, it was usual to form the fire upon a solid hearth in the centre of the room or hut, and the smoke was allowed to fill the space, and to find its way out at a hole provided in the roof, either directly over the fire, or at some distance to one side in order that the rain might not extinguish the fire. The obvious objections to this system led gradually to the universal employment of special smoke-flues, and the inconvenience of the solid hearth led to the invention of the grate which could get rid of the ashes. It is interesting to observe, in modern slow-combustion grates, the employment of the solid hearth.

One or two essential points should be borne in mind in considering the subject of open fires. An open fire does not warm the air of the room by direct radiation to any appreciable extent, but the rays of radiant heat strike the solid objects, such as the walls and furniture, and these heat the air by conduction. A fire of course requires oxygen to keep it burning, and the action of combustion in a fire is of the following nature. Air as it is heated expands, and consequently becomes lighter, volume for volume; a fire therefore causes a column of heated air to rise, and its place is taken by colder air which descends. If the fire be burning out-of-doors in still air, the currents induced will be as shown in fig. 447. The rising of the heated column of air can easily be seen over a fire, or over a gas-jet or other source of heat. The air—a mixture of nitrogen and oxygen—is drawn into the lower part of the fire; the nitrogen is merely heated and passes away unchanged, but the oxygen unites with the carbon of the incandescent material, and forms carbonic acid gas (CO_2). This gas rises through the heated mass, and is changed to carbonic oxide (CO); it then combines with another atom of oxygen, and should pass away as carbonic acid (CO_2), if there is perfect combustion. This is the same gas which is produced by human beings and animals in breathing, and should not be allowed to pass into the atmosphere of a room, although this always takes place where coal-gas, oil, or candles are burnt. The presence of the gas is always undesirable, and when present in comparatively large quantities, it is dangerous to life.

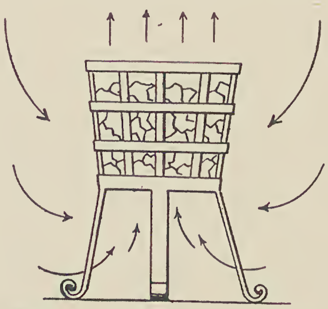


Fig. 447.—Currents of Air produced by an Open Fire out-of-doors.

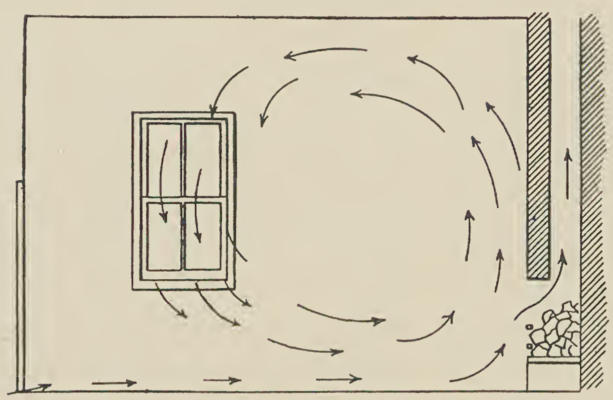


Fig. 448.—Currents of Air produced by an Open Fire in a Room.

The action of an open fire upon the air in a room is represented in fig. 448, from which it will be seen that there is a constant current of heated air rising up the chimney, and to take its place air is drawn from other places, such as the cracks around the doors and windows; if these be carefully stopped up, the fire will not burn brightly but will gradually die out. There is always a current of cold air passing along the floor towards the fireplace. Part of this air passes directly up the chimney, and part is heated by contact with the fire-

place, and rises up the chimney-breast to the ceiling, passes along it, and, as it cools, descends again to the floor level. In a long room, therefore, it is necessary to provide two fires, as the beneficial influence of one will not extend the whole length.

Open fires are unsatisfactory for the purpose of producing uniform warmth throughout the whole air of a room, and also because cold external air from every crack, and the relatively cold air of the corridors, are drawn into the room, producing draughts. The feet of persons in the room are always subjected to a cold current of air, necessitating the use of stools to raise the feet above the floor. In order to diminish or entirely obviate this current, the external air may be brought in by a special duct discharging the air directly under the grate, as shown in figs. 449 and 450. This would supply the fire with air, and would certainly diminish the draught along the floor. It would, however, be a wasteful plan, as the entry of air at such a relatively low temperature, directly under the fire, would necessarily diminish its efficiency and cause a waste of fuel Many attempts have been made to obviate this objection, by passing the incoming air round a portion of the heated structure, before allowing it to come into contact with the incandescent fuel.

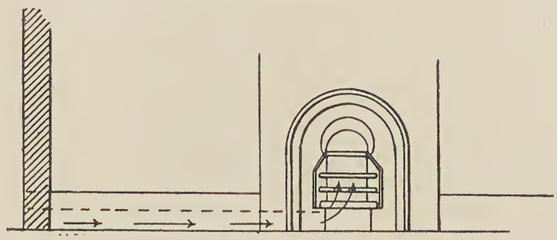


Fig. 449.—Elevation of Fire-grate, with Special Air-duct.

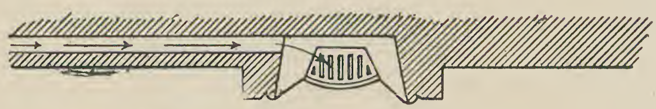


Fig. 450.—Plan of Fire-grate, with Special Air-duct.

The chief advantages of an open fire are its cheerful appearance, and the assistance it gives to ventilation.

A good open fire-grate will conform to certain well-known principles. It must stand well forward. If a fireplace be set back from the room with a flue directly over the incandescent mass of fuel, a very large proportion of the radiant heat must pass directly up the chimney. The aim, therefore, of inventors is to throw the fire well forward into the room, to take away all parts of the structure of the fireplace which prevent direct radiation from the front of the fire, and to promote radiation from the back and sides of the structure.

In order to retain the heat and not allow it to be readily dissipated, the use of iron at the back of the fireplace should be altogether avoided. The next point is to avoid the use of heavy horizontal bars at the front of the grate, and to supersede them by vertical or curved bars, such as are shown in fig. 459, p. 75.

These bars, while effectually preventing the emission of cinders, allow a greater space for the free radiation of heat.

The Nautilus Grate is a kind of slow-combustion dog-grate, lined with fire-brick, and stands well forward into the room, but does not conform to all the principles just stated. A front view of it is given in fig. 451, and a section in

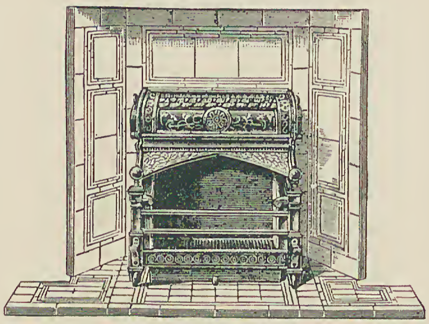


Fig. 451.—Front View of Nautilus Grate.

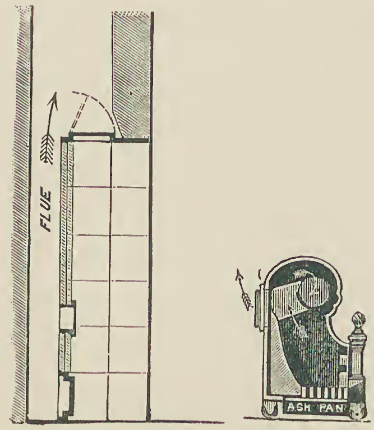


Fig. 452.—Section of Nautilus Grate.

fig. 452. One advantage of this grate is that it can be moved out in summer, allowing the space to be filled with plants. The products of combustion rise, and, after revolving within the central tube, pass off by the nozzles, which may be at the back or at the top; the ashes fall into the special ash-pan. It is usual to tile the sides of the fireplace and the hearth. It will be observed that heat is radiated from the whole exterior of the stove, which burns ordinary fuel, and is lighted in the same manner as any ordinary stove. The makers state that a fire 12 inches wide is sufficient

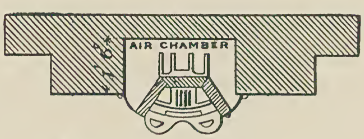


Fig. 453.—Plan of the Galton Grate.

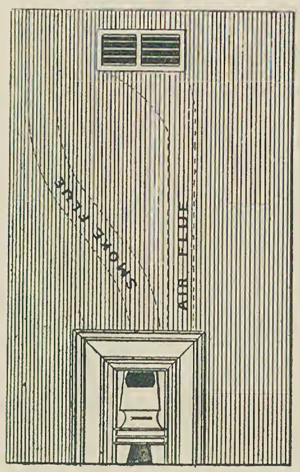


Fig. 454.—Elevation of Chimney-breast, showing Warm-air Flue, &c., from Galton Grate.

to heat a room of 2000 cubic feet capacity, and a fire 14 inches wide one containing 3500 cubic feet.

A special type of grate for warming incoming air was designed for the War Office by the late Capt. (afterwards Sir Douglas) Galton, and has since become known as **the Galton Stove.** Fig. 453 is a plan of this grate; fig. 454 an eleva-

tion of the chimney-breast, &c., showing the warm-air flue, &c.; fig. 455 a section of the room; and fig. 456 an enlarged section of the grate itself. Fresh air is admitted to a chamber formed at the back of the grate, where it is moderately warmed by a large heating-surface; it is then carried by a flue, adjacent to the chimney flues, to the upper part of the

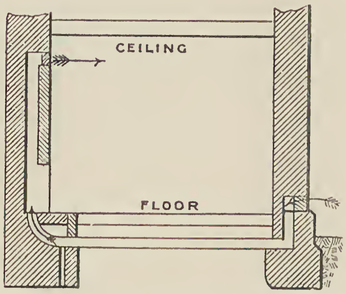


Fig. 455.—Section of Room showing Air-flues in connection with Galton Grate.

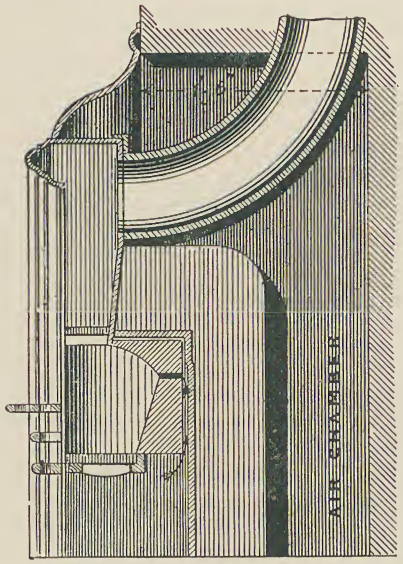


Fig. 456.—Section of Galton Grate.

room, where it flows with the currents which exist in the room. With this form of ventilating grate, the inventor states[1] that the temperature of a room has been found not to vary in any part to a greater extent than 1° or at most 2° F. The body of the stove is of iron, but the fire is placed in a fire-clay cradle; this prevents contact between the lighted fuel and the iron which communicates heat to the incoming air. The radiating surface obtained partly by the back of the grate and its flanges, and partly by the lower part of the smoke-flue, amounts to about 18 square feet.

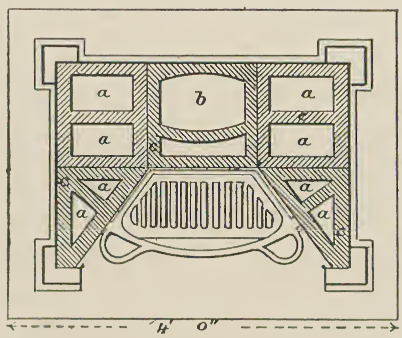


Fig. 457.—Plan of the Galton Independent Stove.

Another form of the Galton Stove, which is in use at the Herbert Hospital, Shooters' Hill, Greenwich, is shown in figs. 457 and 458, the former being a plan, and the latter a section. The chimney *b* passes under the floor, and is placed in the centre of the flue *a*, which brings the fresh air to be warmed by the stove. By utilizing the heat of the flue in this way, more than 36 superficial feet of heating-surface are obtained for warming the fresh air, beyond that afforded by the heating-surface in the air-flues, which is from 12 to 15 feet.

[1] See *Healthy Dwellings*, by Sir Douglas Galton.

The fire stands in an iron cradle, fitted to the fire-clay back and sides, and a current from the air of the room is brought through the fire-clay at the back of the cradle *c*,—where it becomes heated,—on to the top of the fire, to assist the combustion and thus prevent smoke. The top of the stove is coved inside, to lead the smoke easily to the chimney, which passes down into the horizontal flue *b* under the floor. The main body of the stove is a mass of fire-clay, with flues *a* cast in it, up which the fresh air passes from the horizontal air-flue already mentioned, in which the smoke-flue is laid. Thus all the parts of the stove which are employed to warm the fresh air and with which the fire has direct contact, are of fire-clay. The inventor considers that the use of fire-clay is distinctly preferable to the use of iron for such a purpose, as there is less danger of burning the air.[1]

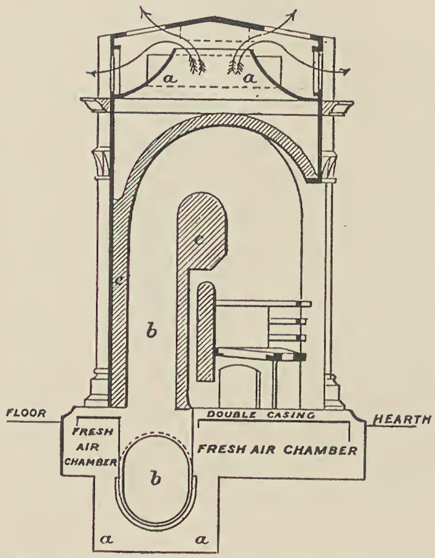
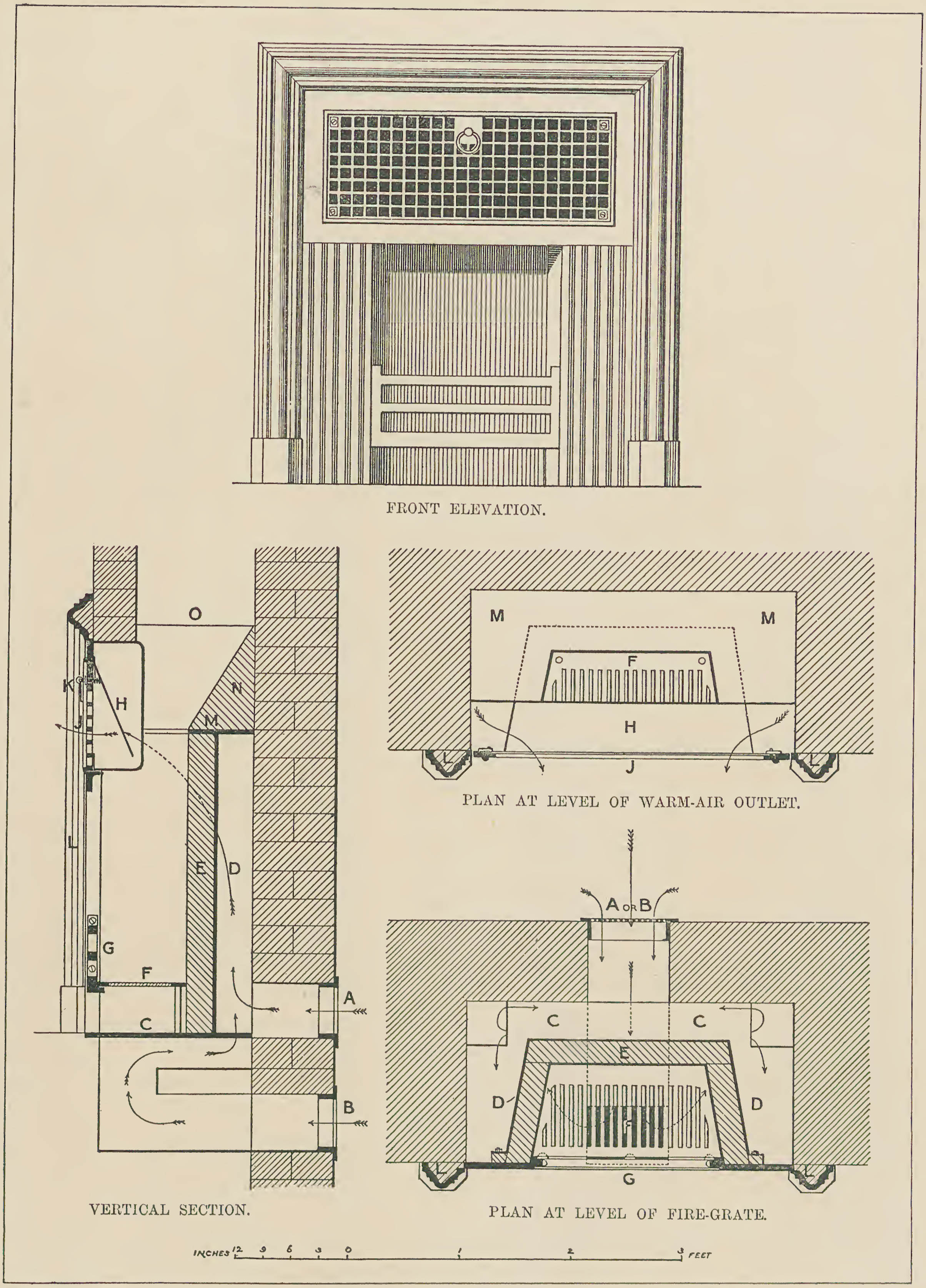


Fig. 458.—Section of the Galton Independent Stove.
a a, fresh-air flues. *b b*, smoke-flue. *c c*, fire-clay.

The Grundy Grate is somewhat similar to the Galton grate, and is shown in Plate XVII. The fresh-air opening through the outer wall is shown at A, or, if more convenient, it can be put lower down as at B, or carried as a channel along the skirting-board or below the floor-boards in either direction. The cold air, entering this flue, passes under the cast-iron base-plate C. If the inlet is at B, the air reaches the warm-air chamber D round the back of the fire-grate, and passes into the room through the warm-air duct H, which has a regulating valve K. The grating itself is lettered F, and the bars G, while the whole of the back of the fire consists of fire-brick, marked E. This grate is made in various sizes with various heating capacities.

It is obvious that **the condition of the warm air** entering the room will be, so far as purity is concerned, exactly the same as the external air, and if this is charged with soot, dust, or fog, these matters will be delivered into the room. In the grates described no arrangement is made to purify the incoming air, and while such fireplaces may be suitable for country-houses, they may not be satisfactory for town-houses. Another point is that, in order to obtain economy in the use of the fuel, it is desirable to block up the space between the grate and the hearth, but this point will be specially brought out in dealing with the following type of grate.

[1] The fire-clay, however, will more easily crack and so admit the smoke into the air-flues.—ED.



GRUNDY'S WARM-AIR VENTILATING FIRE-GRATE.

A. Fresh Cold-air Inlet Grating.
B. Fresh Cold-air Inlet Grating (alternative position).
C. Cast-iron Base Plate.
D. Warm-air Chamber.
E. Firebrick Back.
F. Bottom Grate.
G. Front Bars.
H. Warm-air Duct.
J. Warm-air Outlet Grating.
K. Regulating Valve.
L. Cast-iron Mantel.
M. Cast-iron Sealing Plate.
N. Brickwork Slope.
O. Smoke Flue.

The Teale Grate owes its design, in the first instance, to Mr. Pridgin Teale, F.R.S., a well-known Leeds surgeon. He was convinced that the waste of fuel by incomplete combustion could be easily lessened, even in an ordinary fireplace, if due precautions were taken by means of simple and inexpensive additions.

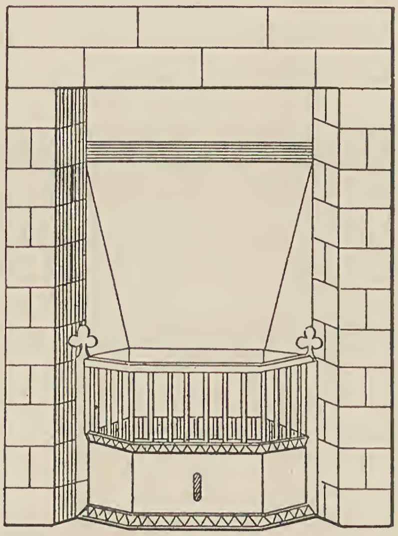


Fig. 459.—Front View of Teale Fire-grate.

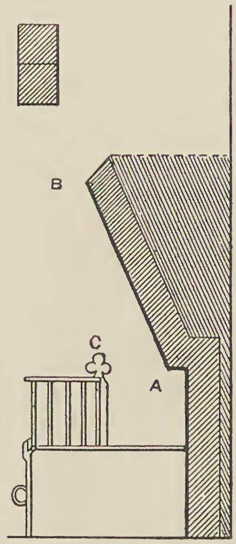


Fig. 460.—Vertical Section of Teale Fire-grate.

Fig. 459 is a front elevation of one of his grates, showing the thin vertical bars, and the economizer, consisting merely of a metal plate fitted in front. Fig. 460 is a sectional elevation, and fig. 461 a sectional plan. The points which Mr. Teale strongly insists upon are these: no air must be allowed to pass in below the grate at all; the space below the grate must be made into a closed hot chamber by means of the economizer; the slits in the grating itself should be made as narrow as possible, and the front bars should be as thin as possible. The whole of the air, therefore, which reaches the fire, arrives at or above the level of the fire, and he considers it desirable to have a solid band, about $1\frac{1}{4}$ inches deep, at the bottom of the bars to hide from view the cinders and dust which are produced. The bottom of the grate should be deep from back to front, probably not less than 9 inches for a small room, or more than 11 inches for a large room. The inventor also lays stress upon the necessity for keeping all

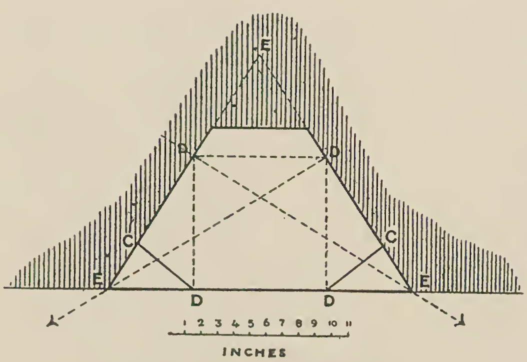


Fig. 461.—Plan of Teale Fire-grate.

iron away from the fireplace. The slope A B (fig. 460) is at an angle of 70° with the horizontal line of the hearth. The plan of the grate (fig. 461) is arrived at by describing a square D within an equilateral triangle E, and cutting off the front angles of the triangle by the lines C D, and the back angle by a line $1\frac{1}{2}$ inches behind the back line of the square.

The Teale grates are now made in a great number of designs; there are, however, **two main types.** No. 1, fig. 462, illustrates the first type, and clearly shows the economizer, the vertical bars, the solid fixed rim forming the base of the bars, the fire-brick back leaning forward and standing out at the bottom away from the back of the hearth proper, and the "covings".

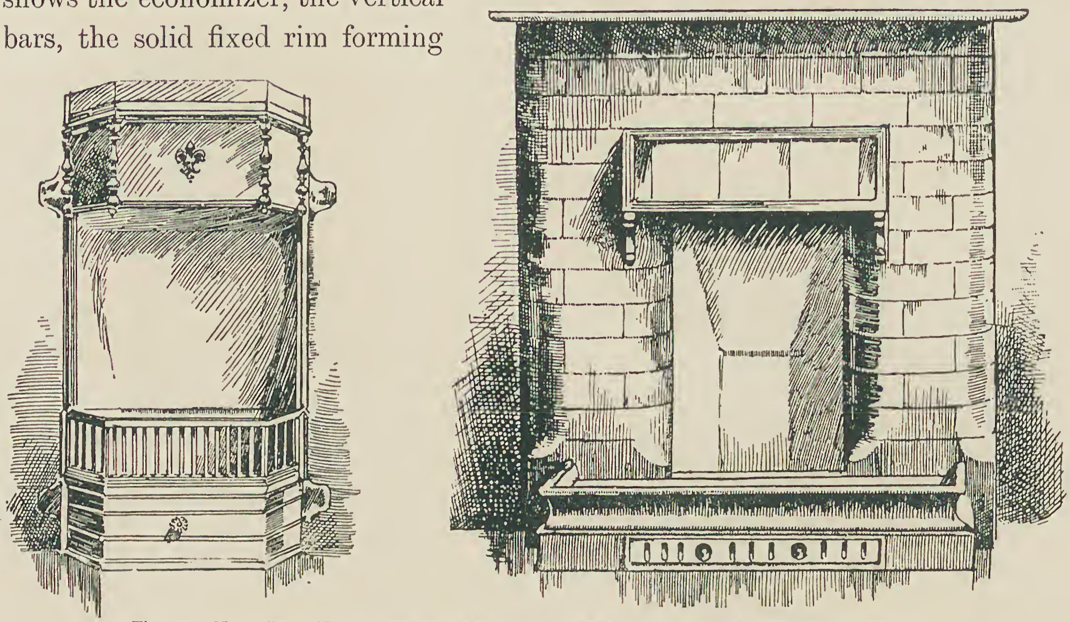


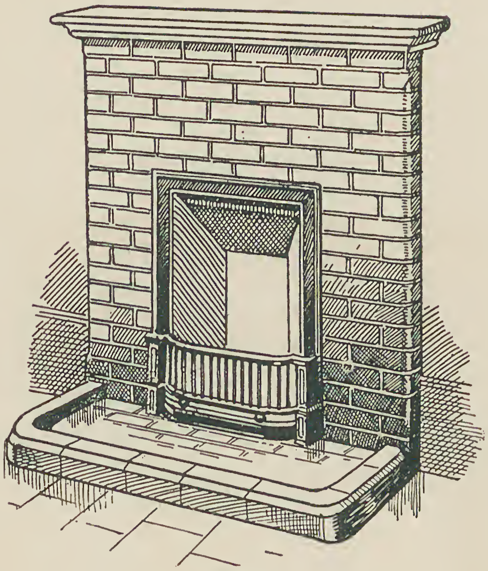
Fig. 462.—No. 1, Front View of the Teale Fireplace; No. 2, Front View of the Teale Front-hob Grate.

The second type, known as **the Front-hob Grate,** is illustrated in No. 2. This has no fire-bars whatever; the fire-clay back and sides are as already described, but the grate is only very slightly above the level of the floor of the room, and a special tiled hearth is built up. This becomes hot, and gives off heat to the room, and thus adds to the efficiency of the grate. Access is afforded to the ash-pit by means of the loose door shown in front, but as this door is provided with several air-inlets, the original Teale principle is departed from to some extent. This type of grate has been found extremely satisfactory.

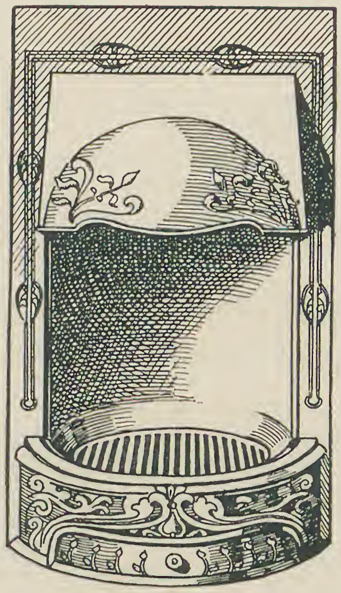
The Rational Grate, not unlike the last, is shown in fig. 71, p. 131, Vol. I.

The Coal Smoke Abatement Society of London carried out a series of smoke-tests of domestic grates in December, 1905, and January, 1906, and the results were published in the latter year. A large number of grates were submitted by

various makers, and 36 were selected and tested under precisely similar conditions in the new government buildings at the corner of Great George



No. 1



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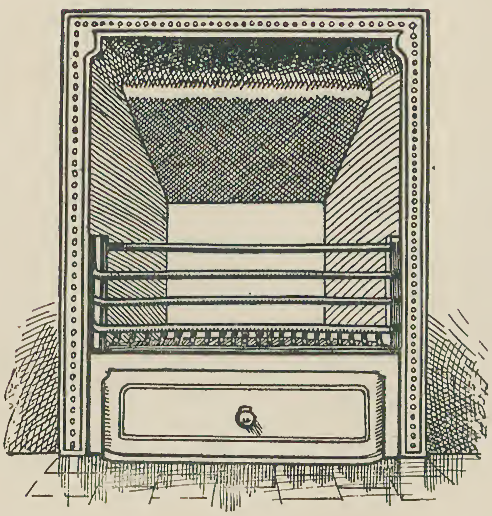


No. 3

Fig. 463.—Three Modern Fire-grates.
1. The "Devon"; 2. The "Draw-well"; 3. The "Hygiastic".

Street and Parliament Street, Westminster. Each fire was tested for 8 hours upon each of 4 days, and from the 36 grates 5 were selected for further tests. As a final result of the whole of the tests, the examiners found that of the grates submitted the "Draw-well" (Messrs. J. & R. Corker), the "Devon" (Messrs. Candy & Co.), and the "Hygiastic" (Messrs. Hendry & Pattisson, formerly Boyd), all of which are illustrated in fig. 463, are the best, showing practically equal results, and that the "Florence" (the London Warming and Ventilating Company) very nearly approximates to them. It should be remembered that all the grates were worked with the object of obtaining their utmost capacity, and not under conditions obtaining in an ordinary room, which would generally be more variable. The fires were not allowed to burn low, therefore the amount

of smoke emitted in these tests was the minimum that can be expected. The actual results obtained for the best three grates are given below:—

Name of Grate.	Name of Firm.	A	B	C	D	E	F	G	H
The "Devon"	Candy & Co.	25·25	2·6	4·0	43·9	51·7	7·8	84·3	0·85
The "Draw-well"	Corker, J. & R.	26·0	1·3	4·0	43·9	52·75	8·8	70·3	0·70
The "Hygiastic"	Hendry & Pattisson (Boyd)	35·9	2·25	5·75	43·9	55·4	11·5	98·1	0·88

A = Amount of coal less cinders plus half wood, in pounds per day of 8 hours; B = Ashes, in pounds; C = Average stokings per day; D = Temperature in the passage outside the room, in degrees Fahrenheit; E = Temperature in the room; F = Difference between D and E; G = Radiation; H = Smoke.

Boyd's Grates, while having the good points of the original Teale design, also possess several other features of interest. Figs. 464 and 465 show a grate with

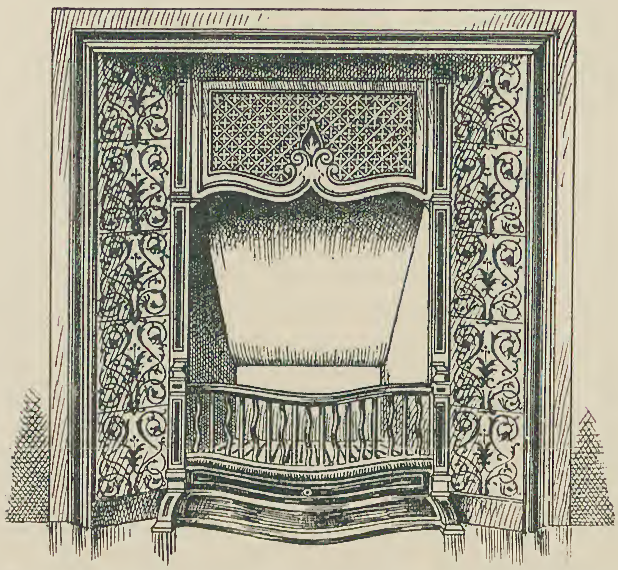


Fig. 464.—Front View of Boyd's Register Grate, with Adjustable Canopy and Regulating Ash-pit.

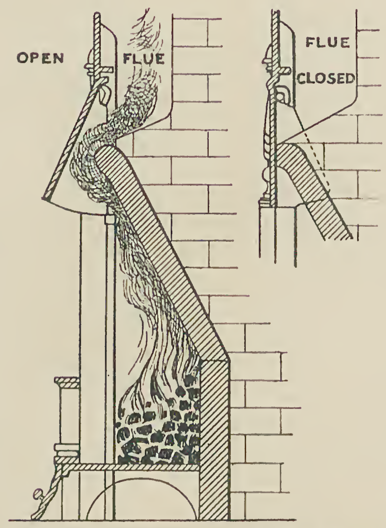


Fig. 465.—Vertical Section of Boyd's Register Grate, with Adjustable Canopy and Regulating Ash-pit.

an ash-pit which may be entirely closed for slow combustion, or opened to any extent desired by simply moving forward the economizer. It has the thin vertical bars and the fire-brick back, but the back slants even more forward than in some of our earlier illustrations, and the canopy register is of a good design, easily regulated to enlarge or diminish the mouth of the flue. The makers of these grates differ from Mr. Teale as to the most desirable angle between the sides and back, preferring an angle of 135°. It is extremely important to keep all the ironwork away from the fire, and this firm has even gone so far as to make the grating itself of fire-clay with slits, as shown in fig. 466. The special

stand for the fire-brick bottom is made of iron, and has an adjustable slide for closing the air-slits. The size of the fireplace can be diminished by the use of suitable blocks, which are specially made to fit the various grates.

The power of a given fireplace may be greatly increased by making it of such a form as to allow the air in the room to circulate round it. This is done in the case of the fireplace shown in fig. 467. In the plan, A is the fuel-basket, B the warming-chamber, and C the brick setting at the back; the V-shaped projections are of iron, and afford a large heating-surface to the air, which passes in at the lower holes and out, in a warmed state, at the upper holes. Such a chamber should be occasionally cleaned out, otherwise it will become choked with dust, and will deteriorate the quality of the air passed through it. The iron just at the back of the fire is protected by fire-brick.

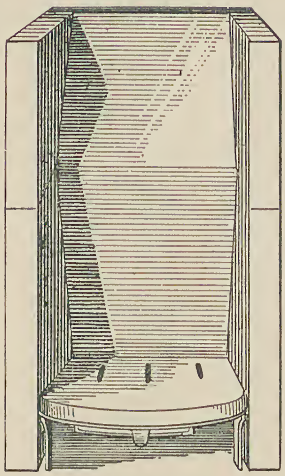


Fig. 466.—Boyd's Grate-body and Grating of Fire-brick.

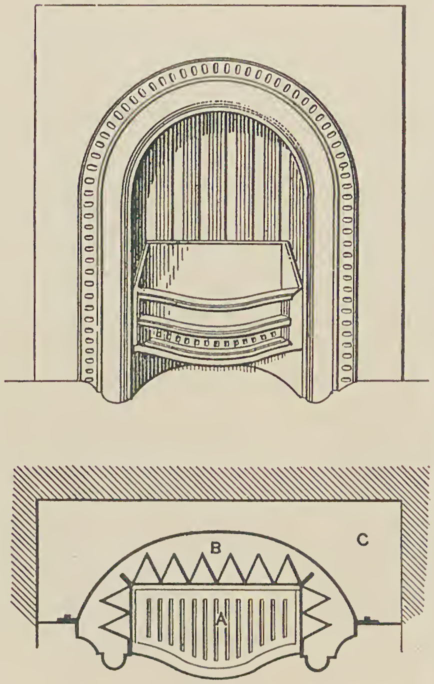
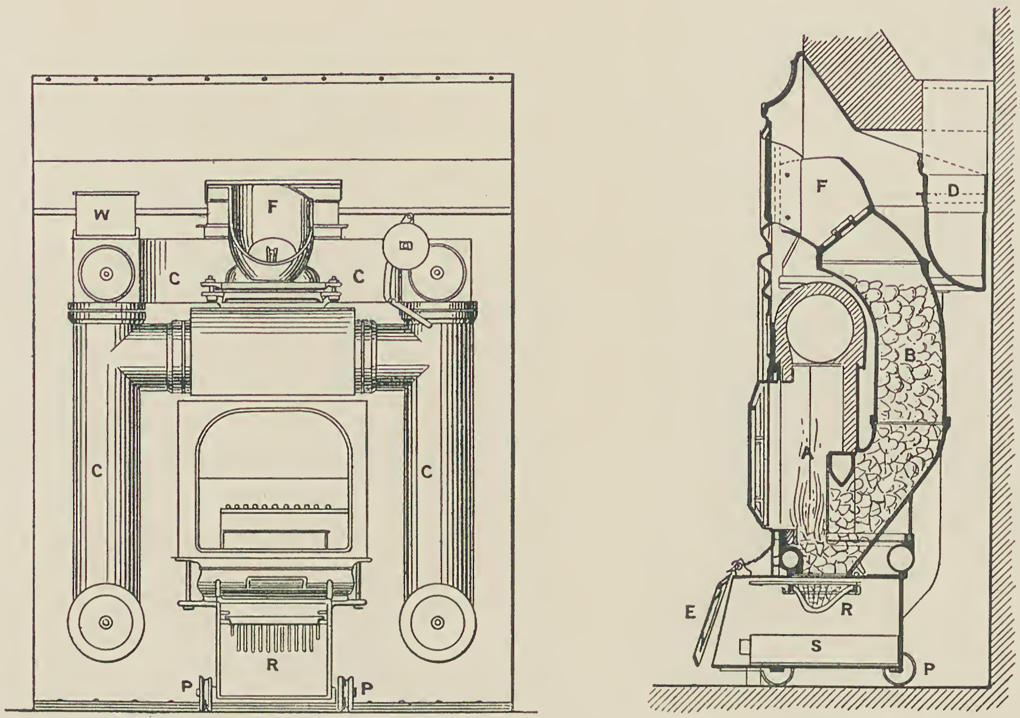


Fig. 467.—Plan and Front View of Boyd's Warm-air Grate.

Heim's "Helios" Smoke-consuming Grates are really stoves, the fire being entirely inclosed. They are specially designed to consume their own smoke. The one objection to them, in the minds of many people, is that the fire itself is inclosed, and the flames can only be seen through a mica door. The design, however, is very ingenious, and well worth describing. The National Smoke Abatement Institution has reported as follows respecting these stoves:—"In the course of twenty minutes the smoke entirely ceased, and the chimney was entirely smokeless during the remainder of the trial. The performances of both

the grate and the stove stand, in point of economy of fuel and efficiency, in the front rank. The fires burned with perfect continuity and regularity, and they were practically automatic in action."

Two views of the Helios fireplace are shown in fig. 468. When the Helios Stove is used with a hopper, it consists of the fire-box A, which is lined with fire-bricks, the hopper B, and the pipe-system C. Under the grate R is



Internal Elevation. Section.

Fig. 468.—The "Helios" Smoke-consuming Stove.

arranged the ash-pan S and the regulating door E. The grate is fed by opening the filling door, and removing the cover in the filling neck F. In the Helios Grate without hopper, the hopper B, the pipe-system C, and the filling neck F are abandoned. The front of the combustion-chamber above the grate is covered by a hinged mica window, which allows the fire to be seen, and possesses the notable advantage of preventing soot, smoke, or burning coals from falling into the room. The whole apparatus is firmly screwed together, and stands on small wheels P, so that it is not a fixture. The heat is diffused partly by radiation and partly by warmed air. The fire heats by radiation through the mica window, and the pipe-system warms the air, which enters cold at the gratings at the bottom of the front, and is returned to the room in a

heated condition through the top perforations at the front. The perforations and mica windows are clearly shown in fig. 469.

By pushing the regulating door as far to the right as possible, the maximum combustion is obtained, while, by moving the door more or less to the left, combustion can be regulated so as to yield the exact degree of heat required. If the regulating door is quite closed, the fire merely smoulders, and, according to the maker's catalogue, burns in that condition about 7 oz. of coal per hour. Economy of fuel is guaranteed by a large area of heating-surface, and perfect control of combustion; and consumption of smoke is attained by injection of pre-heated air on the smoke arising from the fuel. Perfect consumption of smoke is, of course, most important from a hygienic point of view. In grates with hoppers, one charge, it is said, will last from four to twelve hours, according to the heat required. The fire will smoulder all night without attention. To revive it in the morning, it is only necessary to open the regulating door. The replenishing does not affect the burning fuel, so that the fire can be kept alight as long as required. Grates without hoppers hold fuel for 1½ to 4 hours, according to the heat required. Cleaning is necessary once a year. When the heating-chamber is to be cleaned, the grate should first be wheeled out.

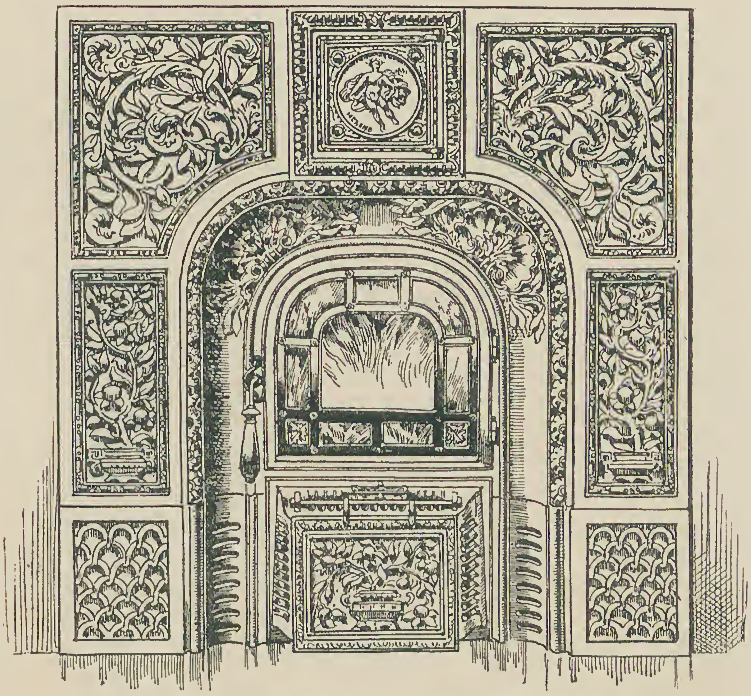


Fig. 469.—Front of the "Helios" Smoke-consuming Stove.

In order to moisten the air, a vessel, which must be daily filled with water, is placed inside the chimney breast. Either the air in the room itself may be passed through the stove, or cold external air may be introduced, warmed, and sent out. Besides this, by an arrangement of suitable flues the warmed air produced in one room may be caused to heat one or two rooms directly over the first. The system then becomes one of heating by warmed air.

These grates, with or without fronts, can be easily inserted into existing mantel-pieces; they are not fixtures. The body of the apparatus surrounding the grate is divided into three parts by fire-bricks; the fire-grate itself forms the middle division. Above this there is an air-channel conducting heated air to the flame, in order to bring about smokeless combustion; above the air-channel there is a register, for the purpose of either allowing a direct draught into the chimney, as in an ordinary grate, or to send the products of combustion through the flues at each side of the grate. These flues can easily be cleaned by removing the cleaning covers, which can also be used as ventilators. In front of the grates there are two sliding mica doors, or one mica door on hinges. The grates are fitted with fronts entirely of cast-iron, or with tile panels, behind which the mica doors slide when opened sideways.

The process of warming can take place in three ways:

(1) If the mica doors and the register at the back are closed, the fire burns with a nice lambent flame according to the position of the lower sliding door, and the grate yields the greatest amount of heat.

(2) If the mica doors are closed, but the register at the back is left open, the grate still burns as described above, but as there is a direct draught into the chimney, only a small quantity of heat is given off into the room.

(3) If the mica doors are open as well as the register, the fire burns as it does in any ordinary grate, and gives hardly any heat into the room, but simply assists the ventilation.

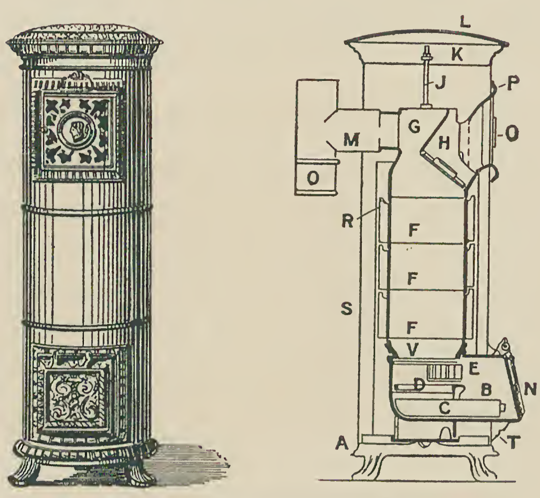


Fig. 470 —View and Section of the "Hestia' Stove.

Ventilation can be obtained by opening the valve in the cleaning covers at the bottom of the side flues; the air from the room will at once be drawn into these flues, giving ample ventilation for several persons. The draught for the fire will be slightly reduced thereby.

The "Hestia" Stove, also invented by Mr. Heim, is a true stove, standing away from the wall of the room, and is shown in fig. 470. It stands on a plain or ornamental pedestal A, and consists of the regulating neck B, with regulating door N, movable grate D, fixed grate E, guard-ring V, one or two middle rings F, filling neck G, with smoke-nozzle and smoke-pipe M. The whole is held together and connected with the

pedestal by two iron rods J. This cast-iron heating-cylinder is surrounded by an inner sheet-iron casing R, and an outer one S, resting on the pedestal. The upper part contains the flat filling-door O, with frame P, and the top is surrounded by a cast-iron border K, carrying a perforated cover L. The smoke-pipe M is connected with the flue by ordinary smoke-pipes. In the regulating neck is the ash-pan C. The poker serves the double purpose of raking out the fire and lifting off the filling cover H. In many cases where iron stoves are used for heating purposes the dryness of the air is a source of complaint; in order to prevent this, the "Hestia" stove has a water reservoir suspended between the inner and outer casing, but free from both, so that the water may become very hot but cannot be made to boil. The reservoir is supplied by a tube opening upwards, projecting from the side of the casing, so that it can be easily filled without removing the cover of the casing. All the fuel is lighted from the top, and combustion proceeds downward, so that smoke and gases must pass through the fire, and are thus consumed before reaching the chimney. As the fire is drawn downward it goes out on the top, so that, in stoves with the several middle rings, black coke is visible on the top, sinking gradually down during the combustion. A further proof of the complete utilization of the fuel, is the fact of the smoke-pipe being almost cold.

In order **to burn coal without smoke,** it must be changed into coke. This cannot be done in an open grate, and the arrangement invented by Mr. Heim affords, in my opinion, a very satisfactory solution of the problem, as the thick heavy smoke, which is given off from the coal, is passed through the incandescent mass on its way to the chimney. There is no doubt whatever that the coal can be burnt without producing smoke, except during the first twenty minutes (say) after lighting, and a choice must be made between the cheerful appearance of an open fire, and the efficient consumption of the fuel in a closed stove.

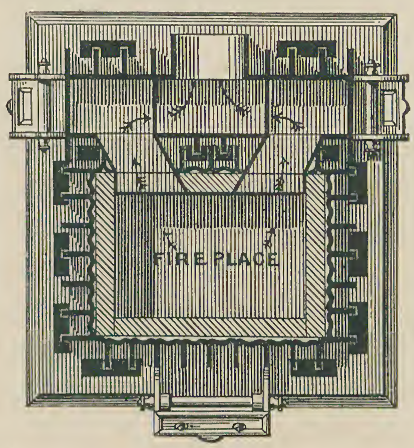


Fig. 471.—Plan of One-chambered Controlled-combustion Heating Apparatus.

The Falkirk Iron Company makes a stove, which is called a "**Controlled-combustion Air-chamber Heating Apparatus**". It consists of an internal stove and an ornamental perforated cast-iron external case, with an air-space between. The plan of the apparatus itself without case is shown in fig. 471, a vertical section in fig. 472, and a front elevation in fig. 473. The bottom and sides of

the fire-grate are of fire-brick. Fuel is inserted at the top, and the smoke-flue descends at the back. The fire-chamber is provided with vertical ribs outside, which project into the air-chamber between the stove itself and the external case. The surrounding air enters at the base of the apparatus, through the holes shown, and passes vertically upwards, and then through the ornamental casing, thus acting as a means of heating by warmed air. If the stove be placed

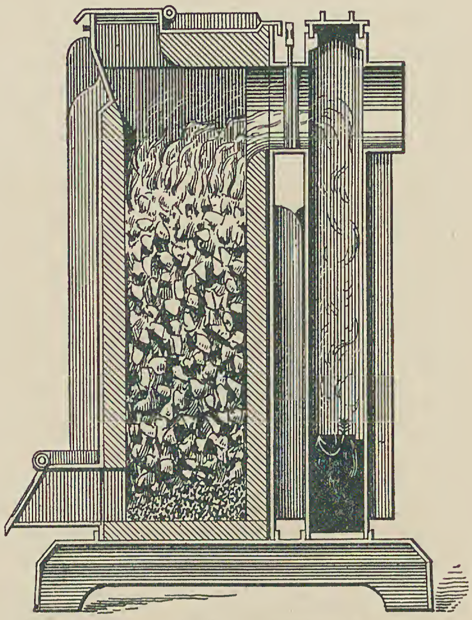


Fig. 472.—Vertical Section of One-chambered Controlled-combustion Heating Apparatus.

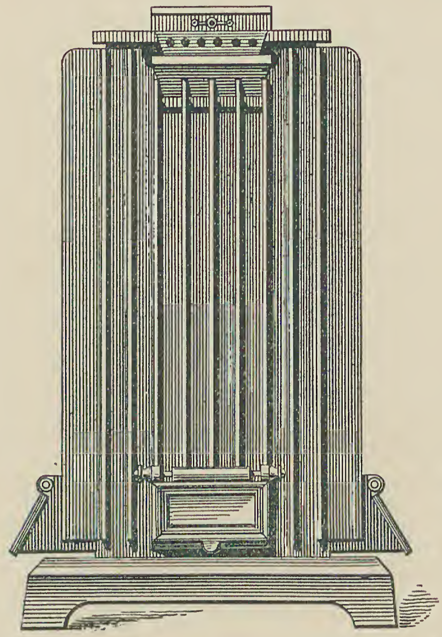


Fig. 473.—Front Elevation of One-chambered Controlled-combustion Heating Apparatus.

over a hole in the floor, connected with an air-duct from the external air, more efficient ventilation will be secured. The makers state that a one-chambered apparatus, as illustrated, with the draught-valve at slow-combustion (or open only $\frac{1}{4}$ to $\frac{3}{8}$ of an inch), will consume 2 lbs. per hour of gas-coke, and heat an apartment containing 40,000 cubic feet of air, at a cost of less than twopence for twelve hours. An evaporating pan placed under the base of the apparatus is found desirable to moisten the atmosphere. The heating-power of the stoves made by this firm vary from 10,000 to 140,000 cubic feet, according to the size of the apparatus. Such a stove is adapted for use in a large hall, and would warm the whole of the staircase and corridors with far less consumption of fuel than would be the case with an open grate.

The Shorland Grate is of the Galton type with a Teale hearth. A section is shown in fig. 474. The back of the grate is of fire-clay, and projects well forward above the fire. Behind it is the warm-air chamber, to which the cold external

air is admitted through a grid in the outside wall. From this chamber, it rises through two special warm-air flues, and is discharged into the room, at a height of about eight feet above the floor, through a hit-and-miss grating. It is of course easy to carry the pipe up through the floor, so as to deliver warm air into a room above. I have already drawn attention to the undesirability of drawing the external air into rooms in town-houses, without previously filtering it in some manner.

The makers say: "In preparing new buildings to receive the Patent Manchester Grates, the best and simplest plan is to build common

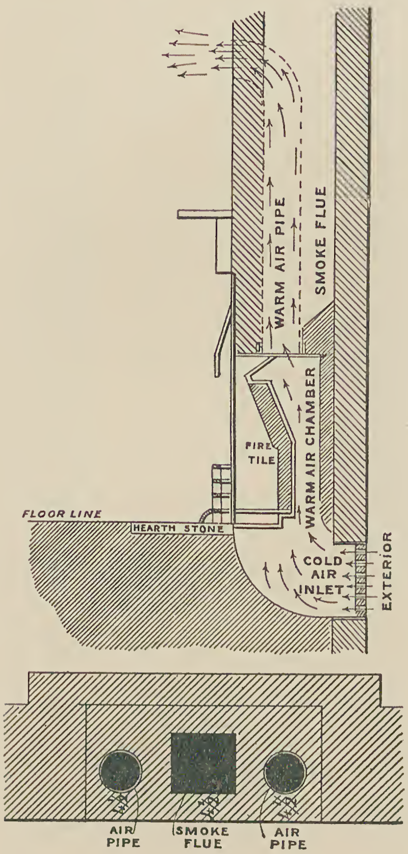


Fig. 474.—Vertical Section of the Shorland Grate and Plan of Flues.

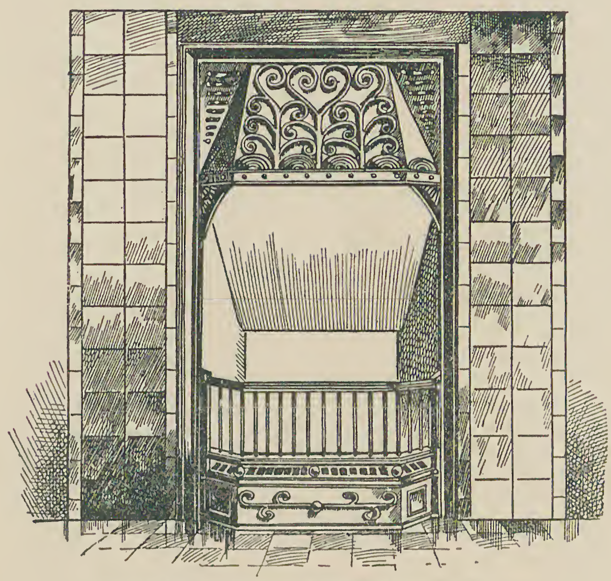


Fig. 475.—Front View of Shorland's Fireplace.

6-inch socketed clay drain-pipes in the solid brickwork of the chimney breast, as the building progresses, for the warm-air flues, keeping them 18 inches apart, $4\frac{1}{2}$ inches from face of brickwork, and commencing 4 feet from floor (socket end upwards). Use square elbows to deliver the warm air into the room through the face of the breast, at about 8 feet from the floor. Then when the building is ready to receive the Manchester grates, they simply require connecting to the clay pipes by means of our own syphon pipes or other connecting pipes. The outside cold-air grids should also be built in as the building progresses." For size No. 1, the opening in the brickwork must be 48 inches high, 30 inches wide, and 14 inches from back to front, and the heating capacity is 3000 cubic feet of space, *e.g.* a room 20 feet long, 15 feet wide, and 10 feet high. Fig. 475 repre-

sents one of these fireplaces. It differs from Teale's in the form of the bars, as the space exactly above the grating is left open instead of having a solid piece to hide the ashes.

An arrangement, which, in my opinion, is of superior merit, is shown in fig 476. This is **Shorland's Calorigen.** It consists merely of an iron box con-

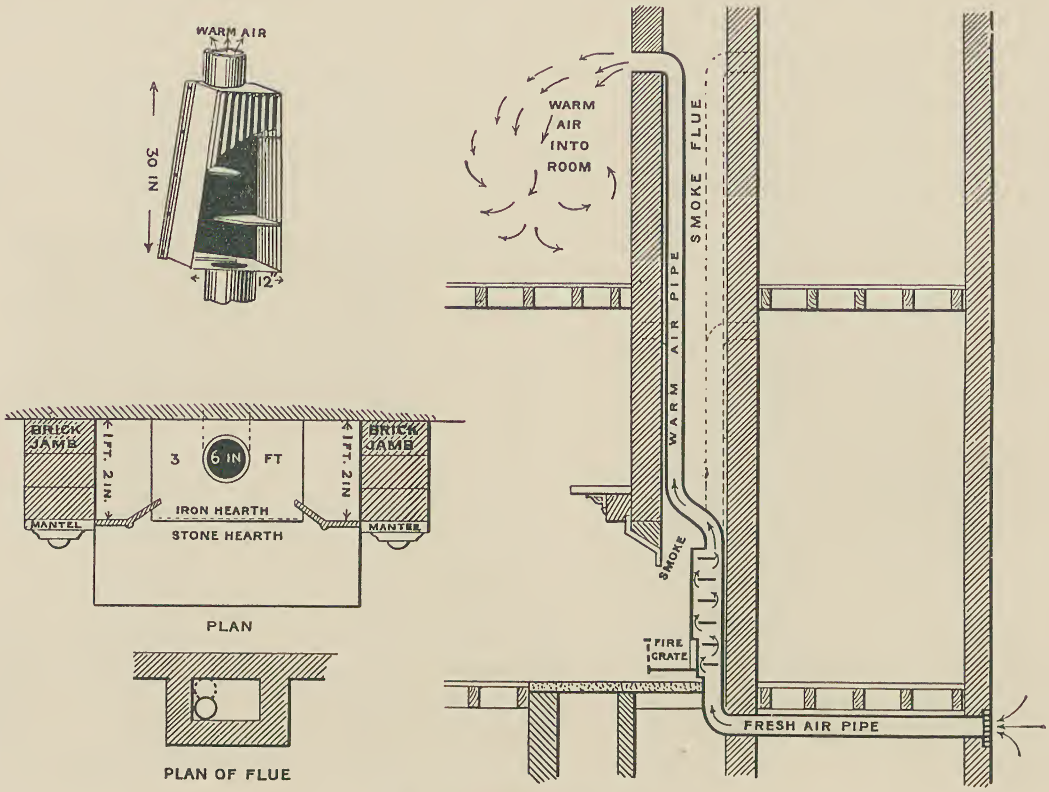


Fig. 476.—Shorland's Calorigen.

taining a series of baffle plates, which is fixed directly at the back of the fire, in a room on the floor below that of the room to be warmed. As the warm-air pipe is of metal, it readily receives heat from the smoke. I would suggest that, wherever it can be done, a case of some kind should be provided in front of the outside grid, in which muslin could be stretched to filter the air to some extent before it enters the room.[1]

The smoke-nuisance is undoubtedly due in a great measure to the imperfect combustion of fuel in household fires. Indeed, some authorities go so far as to say that houses are greater sinners in this respect than factories and workshops. Attention has already been drawn to certain grates in which the smoke is almost

[1] For some critical remarks on ventilating grates and stoves, see Chapter VIII., Section XI., Vol. II.—Ed.

entirely consumed, and something will now be said concerning a process designed to prevent the emission of smoke. It may be assumed that, where open fires are used, it is quite impossible to prevent the production of smoke; the only question, then, is as to whether the emission of the smoke produced can be prevented. Colonel Dulier has succeeded in doing this to a very considerable extent. His apparatus has been in use for some time at the saw-mills belonging to the city of Glasgow, as well as in private houses. The apparatus is very simple. A jet of steam is inserted into the base of the smoke-flue, and the action of the steam upon the smoke facilitates the subsequent treatment, which consists of spraying water upon the smoke. The spray of water is emitted through very small holes in pipes placed inside the smoke-flue, and it has been proved by analyses, made by the City Analyst of Glasgow and by others, that about 94 per cent of the soot, and about half of the sulphurous acid, are in this way washed out of the smoke. This is, of course, a very satisfactory result, especially as the cost entailed in working the apparatus is little more than that of the water required for the purpose, and the action is practically automatic. A considerable part of the residue, obtained by drying the waste brought down by the water, is found to be unconsumed carbon, and this could of course be burnt, if it were found to be worth the trouble.

CHAPTER III.

GAS-STOVES AND OIL-STOVES.

1. *GAS-STOVES.*

That the gas-stove is now so largely and so successfully used, is probably due more to Mr. Fletcher of Warrington than to anyone else. He made the subject of heating by gas a special study, and perfected the use of the atmospheric burner for this particular purpose. It seems a very simple matter to remove the coal from an ordinary fire-grate, attach a small casting provided with a number of holes and an atmospheric burner, and fill the grate with asbestos balls. This, however, is probably the most extravagant method of using gas for heating purposes. The grate is not designed for the purpose, and is much too deep to give the best results; it will probably require the addition of fire-brick inside at the back to diminish its area, and the register must be closed to a very considerable extent, or the chief part of the heat will be lost. If one of

the ordinary fittings is used, such as that shown in fig. 477, it will probably be found that, if the atmospheric burner be turned down, the gas will produce an unpleasant humming noise; this can only be obviated by either turning the gas partially off at the meter, and so throttling and reducing the pressure, or by using a special valve near the meter, such as Stott's Gas-regulator, set for the pressure most suitable for the stove. No atmospheric burner can be made absolutely silent, but if the stove is desired for use in the chamber of an invalid, special attention should be paid to the choice of the most silent burner possible.

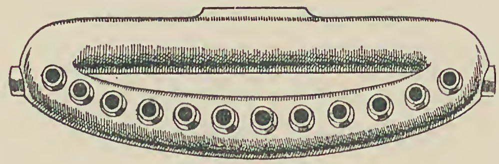


Fig. 477.—Burner for Asbestos-lump Fire in Ordinary Fire-grate.

Too much stress cannot be laid on **the necessity for a flue.** Wherever a gas-stove is used, the products of combustion must not be allowed to enter the room. A mere hole through the wall, with the flue of the stove put through it, is worse than useless, as the draught in such a case is always inwards.

For economy in the consumption of gas a special gas-stove must be used, and of these stoves there are a great number of patterns. If the greatest possible radiant heat be desired, with the appearance of an open fire, the iron fret front should be chosen; the flames of the burners play upon the thin iron, and speedily heat it to redness. The incandescent-ball fire comes next in radiating power. If, however, it be desired to turn the gas low, then a fibrous asbestos front should be used, as with this type the gas-supply may be lessened to a greater extent than with any other.

Fig. 478 represents a stove suitable for placing in front of an ordinary register stove; it has **an iron fret front** 16 inches wide, and would be suitable for a bedroom about 20 feet square. The same kind of grate can be used with the ball-fuel, or with the fibrous asbestos.

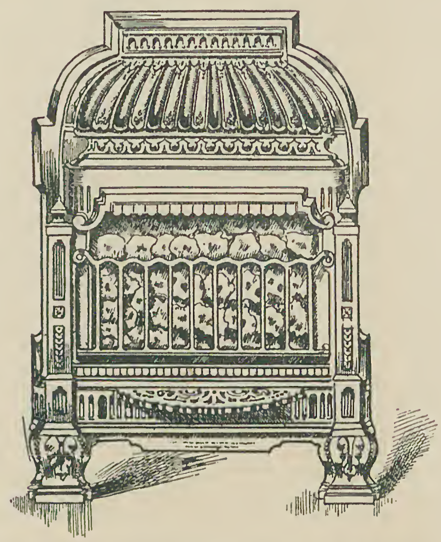


Fig. 478.—View of Gas-stove with Iron Fret Front.

In order to get the greatest value from the heat generated by the gas, it is desirable to pass the products of combustion around the inside of the grate before allowing them to escape to the flue. Such an arrangement is shown in fig. 479, which represents a gas-stove made by Messrs. Fletcher, Russell, & Co., Ltd. It will be seen that the waste gases pass up and down inside special

passages in the exterior casing before reaching the flue; the casing of the stove therefore gives off a great deal of heat. Such a stove requires a good flue, and a $\frac{3}{8}$-inch gas-pipe. It measures $31\frac{1}{2}$ inches high, $24\frac{1}{2}$ inches wide, and $7\frac{1}{2}$ inches from back to front, and is calculated to warm rooms up to 20 feet square.

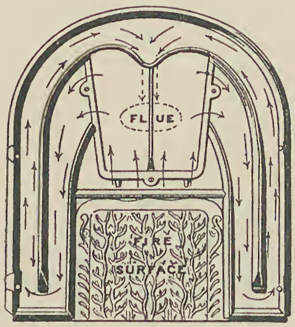


Fig. 479.—Section of Gas-stove with Flues for Utilizing the Waste Heat.

Another form of stove by the same makers, of which a view and vertical section are given in fig. 480, is known as **Fletcher's Tubular Stove,** and gives both light and heat. The cold-air inlet may, if desired, be connected to a pipe carried through the external wall, or the stove may simply be placed in the room; in the latter case a circulation of the air in the room will be set up, the colder air passing in at the bottom, rising through the tubes, and coming out through the grating at the top. The flue must be connected to the chimney-flue, and it may be well to point out that in every case the inlet to the chimney-flue must be stopped by a plate, except where the stove-pipe passes through, otherwise the proper draught will not be obtained. My experience is that, with stoves of this type, it is essential to place a vessel of water on or near them, in order to moisten the air, otherwise it becomes unpleasantly dry. This type of stove is also made with the openings for the air in the front, the tubes being placed horizontally over the burners from front to back of the stove; the fresh air can be drawn from outside if desired.

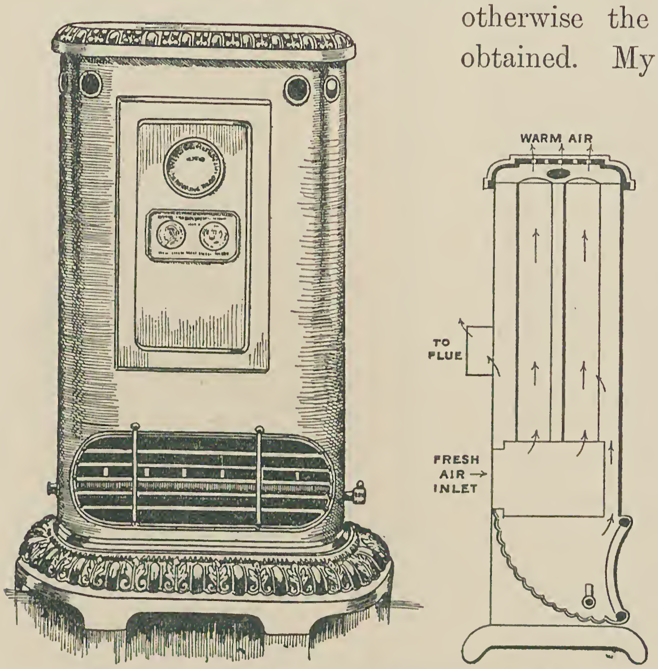


Fig. 480.—View and Vertical Section of Tubular Gas-stove.

The products of combustion of gas consist of water, carbonic acid gases (dioxide and monoxide), sulphur dioxide, and other gases, depending upon the impurities in the gas. Stoves are made which are called "**condensing stoves**", and which depend upon the cooling action of certain surfaces; the vapour of

water produced by the combustion is deposited in the form of drops upon these surfaces, and the water takes up the sulphur dioxide, forming sulphurous acid, and falls down into a special receptacle, which needs emptying frequently. The objectionable smell, usually emitted by a gas-stove unprovided with a flue, is done away with, but the invisible and injurious carbonic acid gases are unaffected and are therefore given off. For this reason, I consider that no gas-stove, whether of the condensing type or any other, should be used without a flue, if proper attention to health is given. The general public appear to believe that a "condensing stove" does away with *all* the products of combustion, but this is an entire delusion. It may, however, be considered that a condensing stove is of no greater detriment to the air of a room than the ordinary gas-burner, used without either special inlet-flue or outlet-flue for the air. This is of course true, but it must be remembered that a stove may consume a far larger quantity of gas than a number of burners; it is also upon the floor, and the heated carbonic acid gas rises easily to the breathing level, whereas, in the case of gas for illuminating purposes, the foul gases are often carried off through the ventilating outlets, which may be near the ceiling.

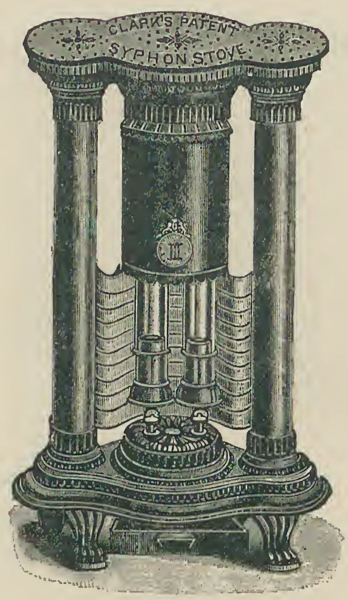


Fig. 481.—"Syphon" Condensing Gas-stove.

Another form of condensing stove, known as Clark's **"Syphon" Hygienic Condensing Gas-stove,** is illustrated in fig. 481. It consists of two Argand burners with the usual chimney tubes, and the particular type illustrated is stated to consume 16 feet of gas per hour, when turned full on, and to heat a room about 18 feet by 18 feet. Below the stove itself is the drip-tray, into which the water falls, as it is condensed. I cannot lay too much stress upon the fact that, although the greater part of the objectionable odour proceeding from the gas-stove without a flue is done away with, yet the large volume of carbonic acid gas is delivered into the room. This stove is intended to be used without a special flue, and some of the advantages claimed for it by the makers are that no flue is required, that no smoke, smell, or dirt, is produced. By the use of a water-vessel, the air can be rendered moist if desired. In passing, I may remark that it is especially desirable in a sick-room, where the patient is suffering from bronchitis, asthma, or other troubles of the respiratory organs, that the air should be moist, and it is usually better to make use of a wet blanket placed

over a chair near the fire, than of a special kettle; the moisture will pass from the blanket readily in the form of vapour.

Flat Stoves have also been specially designed for use under floor-gratings,

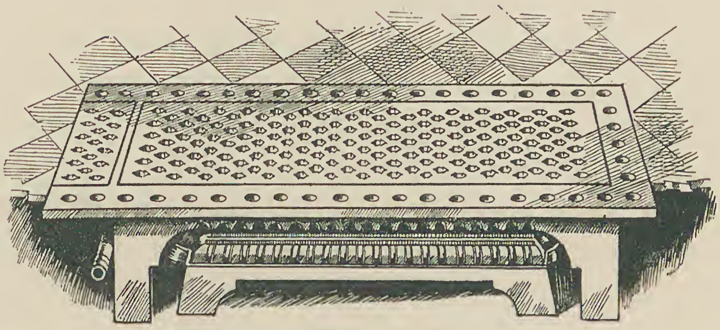


Fig. 482.—Flat Gas-stove for fixing under Floors.

and one of these is illustrated in fig. 482. The same remark applies to such stoves as to those already described, that, unless the products of combustion are carried away by a special flue, they will be found very objectionable.

In May and June, 1906, **the Coal Smoke Abatement Society** tested twenty-five different gas-stoves, which had been temporarily fixed in the new Public Offices, Westminster. Each room had a capacity of about 4000 cubic feet, and all were upon the same floor. All the flues were 68 feet high and 9 inches in diameter inside, and the bottom of each flue was completely closed with sheet-iron, which had an opening just large enough to allow the flue of the gas-stove to pass through. The pressure of the gas was kept constant at $\frac{12}{10}$ths of an inch. Air could only enter the room by the doorway, as each door was fitted with a stop, so that half an inch clear opening was left on the latch side when the door was closed. The tests were directed towards finding out the thermal efficiency of the stoves, and their effect upon the air of the rooms from a hygienic point of view. Each stove was tested for a period of 8 hours continuously, and the results were carefully tabulated, eight of the stoves being finally selected as giving the best results, namely, Cannon Co.'s "Iris" and "Victory" (large); Main's "Chelsea"; Fletcher's "India"; Richmond's "Royal Sovereign" and "Ilford"; and Davis's "Beaufort" and "Albany". The most important conclusions of the examiners may be summarized as follows:—A properly constructed gas-stove with a flue sufficiently large to carry away the products of combustion, although for constant work more costly than a coal fire, is quite as satisfactory from a hygienic point of view, and does not in any way vitiate the air of the room, nor does it produce any abnormal drying effect as is popularly supposed. It is only in the very largest gas-fires that the calorific

value of the fuel burnt approaches that obtained in coal fires; in the majority of cases it is only about one-third. Of this calorific value a higher percentage is utilized in warming the air of the room with the best coal fires than with gas-fires, when once a steady temperature has been attained, the ratio being roughly 3 to 1 in favour of the coal fires. A point in favour of the gas-fires is that they can be easily regulated, and the heat of the room controlled in a way which is not possible with coal fires. The gas used in the eight stoves which gave the best results varied from 23 cubic feet to 66 cubic feet per hour, but this was because the stoves varied greatly in size; the larger ones of course heated the rooms to a higher temperature than was possible with the smaller ones. The air of the rooms was analysed for impurities; to detect carbon monoxide the hæmoglobin test was used, and for quantitative estimation Dr. J. S. Haldane's method was applied. In this test the estimation of carbon monoxide depends upon the intensity of the pink tint produced in diluted blood on shaking it up with air containing carbon monoxide. For other impurities the potassium permanganate test was adopted.

2. *OIL-STOVES.*

Where gas cannot be had from a public supply, oil-stoves are often useful; but the price of oil has now risen so much higher than it was some years ago, that it will be found in most cases much more economical to use coal for permanent work, but where portability is an advantage, the oil-stove has many points in its favour. There are now several very satisfactory stoves upon the market, among which we may mention those known as Rippingille's. The type of burner has recently been improved, and now the flat wick is used instead of the circular. In fig. 483 is shown a large type, known as the "Emperor". The oil-tank is of cast-iron in one piece, and is fitted with two 6-inch burners with patent extinguishers, in separate cylinders; the frames and radiators are of cast-iron, with large mica windows. The stoves are also made with very ornamental cast-iron cases. The same remarks apply to the use of oil-stoves as I

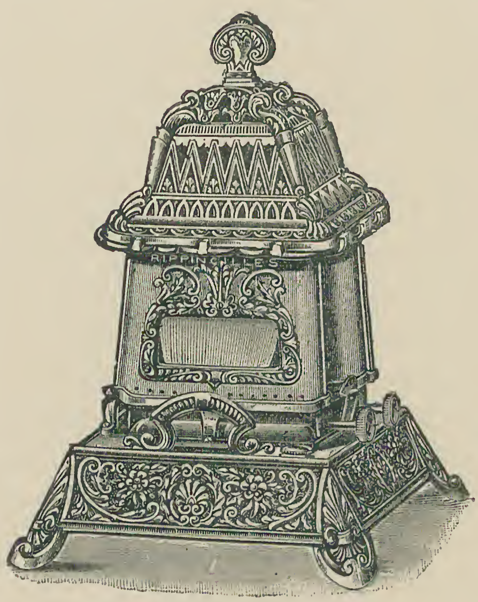


Fig. 483.—The "Emperor" Oil-stove.

have already made with regard to gas-stoves, except that the sulphurous acid fumes are not present, but it is obvious that where so powerful a burner is used without a flue, the amount of carbonic acid gas given off must be very considerable.

A type of so-called **condensing-stove** is also made for burning oil, and, of course, the same method of adding moisture to the heated air can be adopted as was described in connection with the gas-stoves.

CHAPTER IV.

HEATING BY HOT OR WARMED AIR.

Before describing the various systems by which the dwelling-house may be heated by hot or warmed air, it may be well to say that to use this as the sole method of heating, to the exclusion of open fires, will not, in my opinion, commend itself to the average British householder. Rightly or wrongly, **we are so wedded to the system of open fires,** that their cheerful appearance would be greatly missed, and would hardly be compensated by even an equable warmth all over any given apartment. It would, moreover, be very difficult, and in some cases practically impossible, to apply such a system to an old house, although it could easily be arranged for in the design of a new one. There can be no doubt that the mere cost of fuel burnt would be less, if a system of heating by hot or warmed air were applied, instead of the usual system of open fires, but the difference in the cost of fuel on the two systems would not be sufficient in most cases to turn the scale in favour of the hot-air system.

In many parts of the continent of Europe, and in the United States and Canada, the winters are very much more severe, and the variations of temperature much greater, than in the British Isles, and in these cases it is found absolutely necessary to resort to means of heating more efficient than the ordinary open fire, and for this reason large close stoves, placed at some distance from the walls of the rooms, are frequently used; hot-air warming, however, has found wide acceptance in North America, though more, I believe, for public buildings, such as schools, than for private residences.

Before describing the various methods of heating buildings by means of warmed air, it will be well to allude to some of **the principal points which require attention:**—

(*a*) *Cleanliness of the air* is essential, and therefore, if the external air be loaded with soot and dust, it must be passed through some filtering material before being delivered into the living-rooms.

(*b*) *Freedom from disease-germs and noxious gases* is also essential; it is therefore necessary to choose the position of the inlet with careful attention to the position of gullies, ventilators to drains, and apparatus of a similar nature.

(*c*) *Humidity of the air* requires careful attention; the higher the temperature of the air, the more water-vapour it will hold in suspension. It is therefore obvious that, if relatively cold external air be heated and passed direct from the heating-apparatus into the living-rooms, it will be in the best condition for taking up moisture, and, while eminently fitted for use in the drying-closets of a laundry, it is very ill-adapted for breathing, and will necessarily cause the skin to feel parched, and the nose, mouth, and breathing-organs will be made dry and uncomfortable by the abstraction of their natural moisture. It is, therefore, very desirable that the air before delivery into the rooms should have imparted to it the proper humidity necessary to render it pleasant for breathing.

(*d*) *The requisite volume of air* must be passed in at such a velocity as to cause no perceptible draught, and it must then be extracted by a suitable flue of a height calculated to produce the requisite constant flow of air through the building.

(*e*) *The regulation of the temperature of the incoming air* must be provided for by a system of simple valves.

(*f*) *The air must not be heated too much*, otherwise the dust particles will be burnt, and a distinct and characteristic odour will be produced, which is very unpleasant.

In describing the Galton Stove and others of the same type, I have already stated that **dust and other matters** may be carried in with the incoming air. With a system in which the flow of air through the heating-apparatus, and thence through the house, is solely induced by the heated column of air in a flue, it is usually found impossible to obtain sufficient suction to permit of the use of a filtering-apparatus, and therefore recourse has to be had to some means of increasing the draught in the flue, either by the use of a fire at the bottom of it, by the use of a radiator in a similar position, or by mechanical means, such as a rotary-fan. In the Houses of Parliament, which are heated by carefully-humidified air, both fans and fires are used for causing the proper currents of air; but in the case of a house, it is desirable to avoid complication as much as possible, and I should deem the use of a rotary-fan to be undesirable except in a very large mansion.

If air be passed directly through the flue-tubes of an apparatus in which the products of combustion of the fuel play directly upon the tubes, there is always a risk that, by inattention on the part of the attendant, the surface of the tubes may become overheated; and then, instead of being warmed, **the incoming air will be burnt.** The results obtained depend entirely upon the temperature of the heating-surfaces, and upon the velocity of the air.

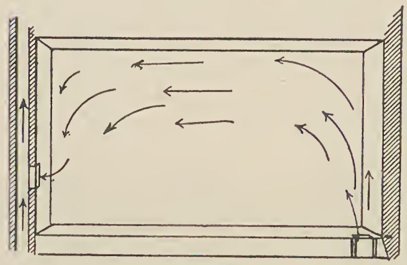


Fig. 486.

If the temperature in a living-room be examined at the floor-level, and at different heights above the floor, while artificial means of illumination are being used, it will

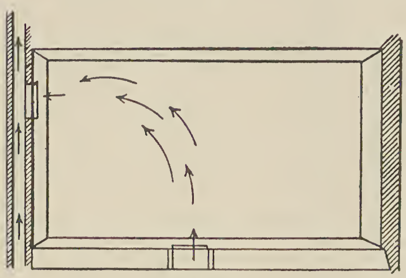


Fig. 484.

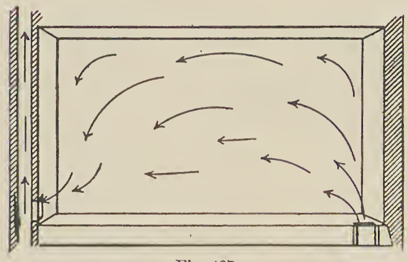


Fig. 487.

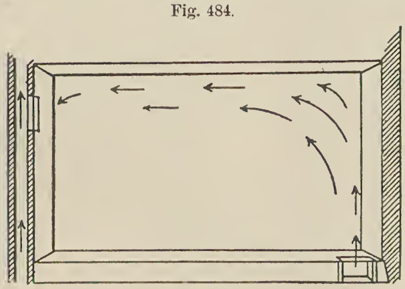


Fig. 485.

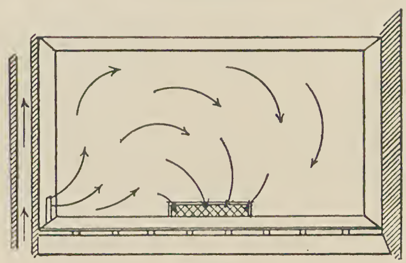


Fig. 488.

Figs. 484 to 488.—Various Arrangements for Entrance and Exit of Warmed Air.

be found that the air near the ceiling is extremely hot and much vitiated by the products of combustion of the gas, oil, or candles used for illumination, and also by the products of respiration. I am of course alluding to the usual arrangement where gas is burnt freely in the air, with no special flues for feeding the gas-jets with external air or getting rid of the products of combustion.

In the United States, **Smead's system of heating by hot air** has been very widely used in public schools and other buildings, and is stated to have given great satisfaction. Before describing this system, I shall borrow from Mr. Smead's work on the subject five illustrations (figs. 484 to 488), showing the results of various arrangements for the entrance and exit of the air. In fig. 484

the heated air enters through a grid, fixed in the middle of the floor, the result being that a column of heated air rises in the middle of the room and passes away near the ceiling, leaving a stagnant mass of cold foul air. The arrangement in fig. 485 is very similar. That in fig 486 shows a slight improvement, while fig. 487 shows direct displacement of all the cold air by the warmed air,

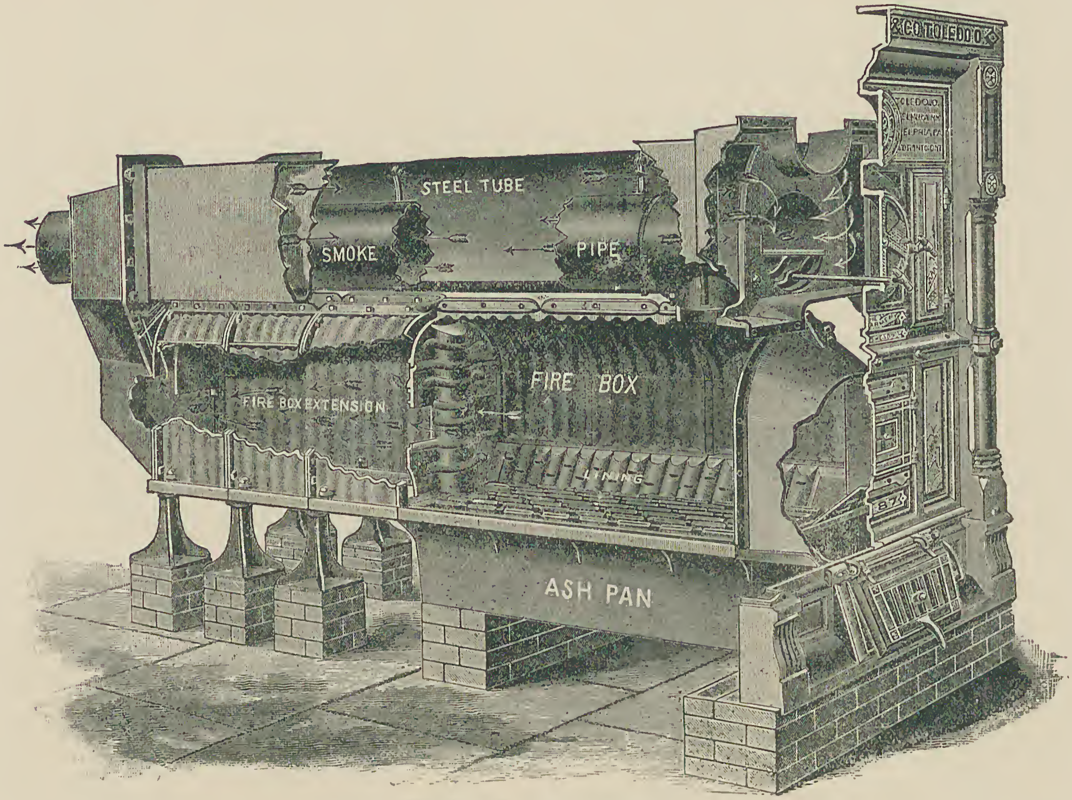


Fig. 489.—The "Smead" Furnace.

and fig. 488 shows an additional improvement by using a number of outlets at the floor-level, and then passing the foul air out between the floor of the room and the ceiling of the room below. It will be observed that no account is taken of the fact, that the products of combustion of the gas in the ordinary way would be taken down to the breathing-level.

In my opinion, there are several objections to the Smead system. One is that the products of respiration, and emanations from the body, which would naturally pass upwards (as they leave the body at a temperature of 98° Fahr.), are carried downwards in the current of air to the outlet near the floor, and the air thus vitiated must be breathed over again, which is undoubtedly a bad feature. The second objection is that, in order to keep a room warmed to

(say) 60° or 65° Fahr., the incoming air must necessarily be at a much higher temperature, probably about 120° Fahr. This current of heated air is most objectionable to any person standing or sitting near the inlet; but this latter objection is not confined to the Smead apparatus, but is common to all systems in which heated air is relied upon as the sole means of warming the rooms.

The Smead apparatus consists of a special type of air-heating furnace, and a system of inlet and outlet flues. The furnace is shown in fig. 489, which

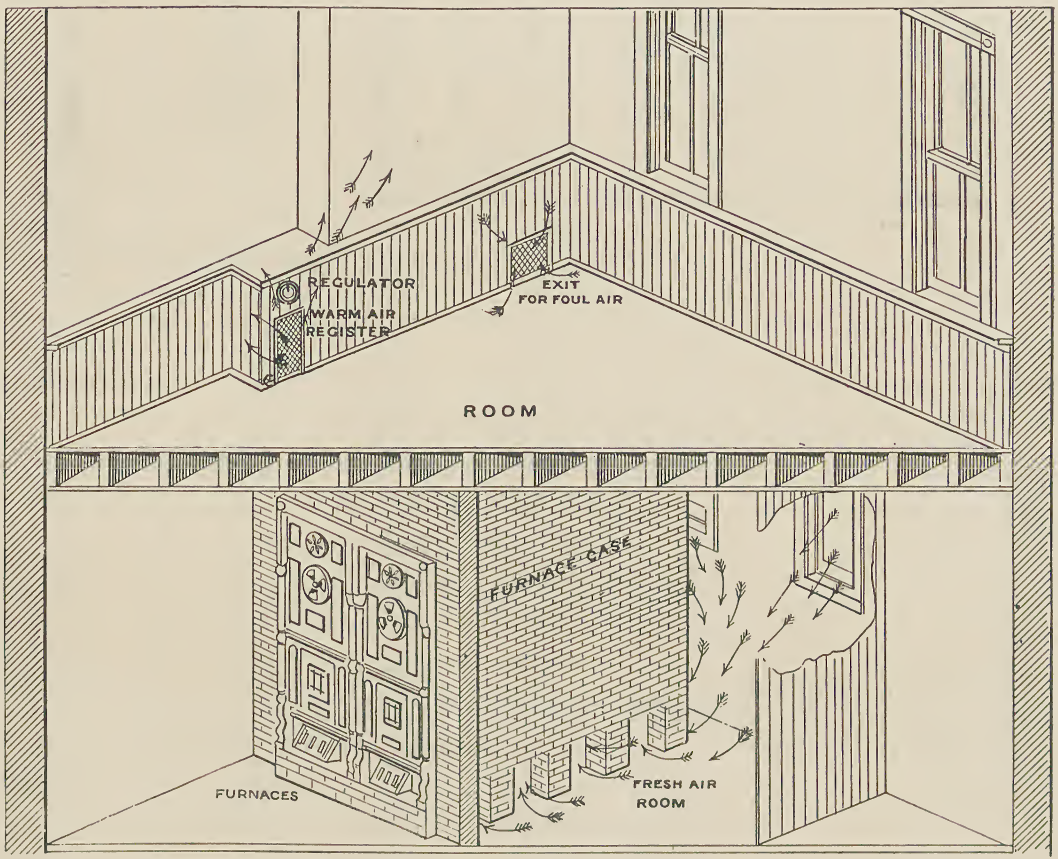


Fig. 490. View of "Smead" Furnace set in Brickwork.

represents a type which has been gradually perfected from a much inferior form. The heater itself is inclosed in brick walls, which form a complete box round it, and it is placed as shown in the perspective view, fig. 490. The furnace is built in a special fresh-air room provided with large inlets from outside. The cold external air enters this room, and is drawn through the openings in the brickwork around the heater; it rises over the highly-heated iron surfaces of the heater, and then passes up the wall-flues to the different rooms. As a rule, one flue is arranged for each room, so that trouble may be avoided from baffling.

The system of inlets is very clearly shown in fig. 494, from which it will be observed that the inlet-flue is carried up a little above the floor-level, and is

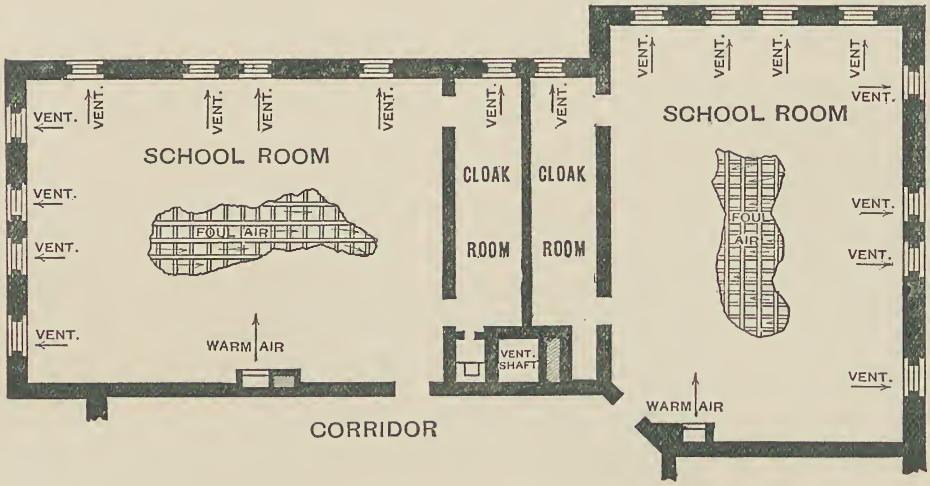


Fig. 491.—General Arrangement of Inlets and Outlets in the "Smead" System.

stopped there; the outlets are in each case close to the floor, in the wall opposite the inlet, as shown in fig. 491, and communicate with the upcast shaft. In plan the shafts are arranged as shown in fig. 492. The smoke-flue is next the ventilating shaft, so that the latter is kept constantly hot; they should be carried to a height above the roof of the building, sufficient to ensure freedom from the baffling caused by conflicting currents.

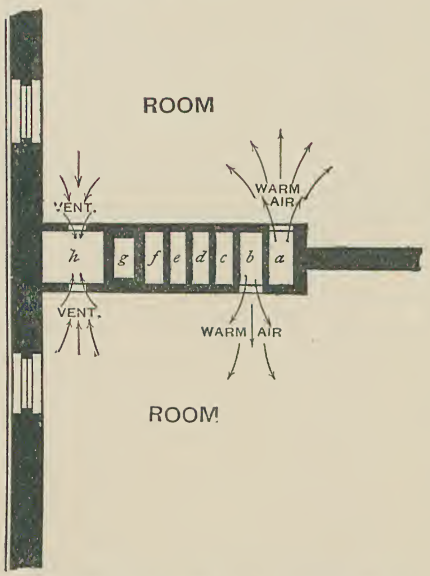


Fig. 492.—Plan showing Stack of Inlets and Outlets, "Smead" System.

a, *b*, warm air to first story; *c*, *d*, warm air to second story; *e*, *f*, warm air to third story; *g*, smoke flue; *h*, ventilating shaft.

The arrangement for the regulation of heat is very ingenious. A view of the register and regulator, as seen from the interior of the room, is given in fig. 493. It will be seen that the register is designed to give the maximum amount of opening possible, and is of very ample size, so that the current of air entering may be of low velocity. Just above the register is placed the regulator, marked for warm air and cold air, and any desired mixture can be obtained by means of a very simple and effective valve, which is shown in fig. 494.

It is quite obvious that if the Smead system of heating is to be applied

successfully to a building, that building must be originally designed for it. The system has been very largely used in the United States, and appears to have there given great satisfaction. A very elaborate work has been published by the Isaac D. Smead Company of Toledo, which is full of coloured plates. The book is well worthy of careful study. The system appears to be very economical in the consumption of fuel, and there can be no risk of explosion as is the case with the use of hot-water and steam plant. The incoming air is not, as a rule, washed or screened in any way, and is passed into the rooms at a temperature of about 120° Fahr. I am not aware that the air is humidified; no mention is made of this in the work alluded to. It is, however, obvious, that to heat air at even freezing-point up to 120° Fahr., without adding to it the requisite amount of moisture, must render the atmosphere in the rooms very dry, and in some cases this may be found objectionable. The mere heat of the incoming air will also probably be found uncomfortable to a person placed near the inlet, although it must always be borne in mind that air at such a temperature, or even higher, will rise in the vicinity of a close stove, and if the current of air passing over a hot-water or steam radiator be slow enough, the air may acquire a temperature considerably higher than that of the general body of air in the room.

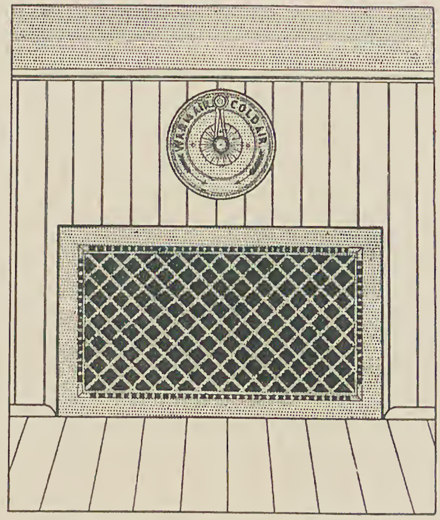


Fig. 493.—View of Register and Regulator.

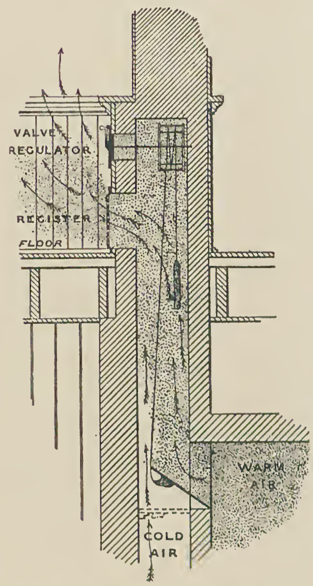


Fig. 494.—Section of Duct showing Valve for Incoming Air.

The Heim System is the invention of Mr. H. Heim, an Austrian, and has been very largely adopted in Austria, Hungary, and other parts of Europe. The system consists of a central heating-apparatus, which is smoke-consuming, and is known as the Calorifer; this heats air brought from the exterior, and the heated air is delivered through specially-formed ducts or flues, prepared in the original design of the building. The same system may, however, be applied to portions of a building, or even to single rooms.

The arrangement of the Calorifer is shown in figs. 495 to 498. The channel D (figs. 495, 496, and 497) surrounds the grate, and is connected with the outer

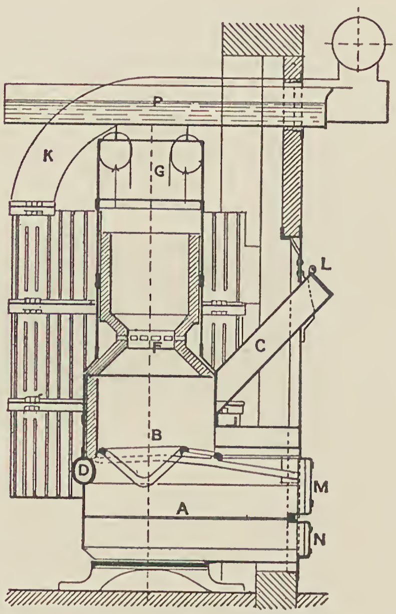


Fig. 495.—Vertical Section of Calorifer from Back to Front.

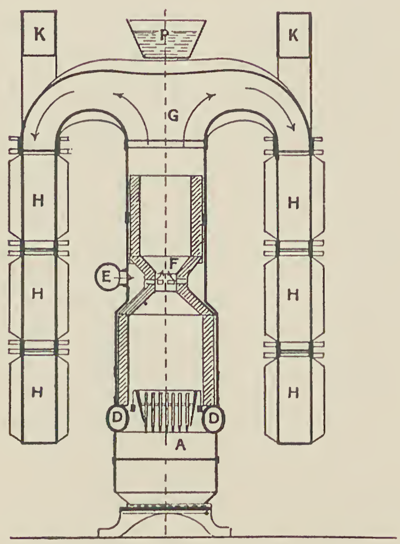


Fig. 496.—Vertical Section of Calorifer from Side to Side.

air, which is admitted and regulated by means of an adjustable valve. This channel introduces heated air under the grate, to ensure perfect combustion. The part of the filling and combustion chambers most exposed to the fire is lined with fire-bricks, which are cone-shaped towards the centre at F (figs. 495 and 496), so as to form, together with the cast-iron outer partitions, one channel, which is connected with the outer air similarly to the channel D. The action of this channel is likewise regulated by means of an adjustable valve. Through this channel highly-heated air is brought in contact with the products of combustion, ensuring a complete consumption of the smoke. Those parts of the combustion-chamber which are not lined with fire-bricks have smooth, ribbed, or fluted sides, according to the heating-surface required. On the uppermost casting of the combustion-chamber there are four nozzles, from

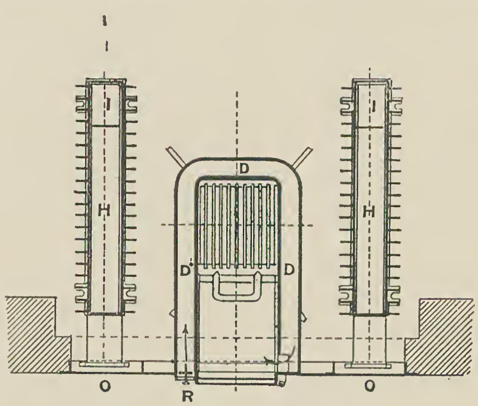


Fig. 497.—Plan of Calorifer.

which the radiators H (fig. 496) are suspended freely, to allow for the expansion and contraction of all parts of the Calorifer, and so avoid the straining which causes loose joints and consequent leakage, so usual in other heating-apparatus. Through these radiators, which are also made smooth or ribbed according to the heating-surface required, the products of combustion are taken first downwards at H, and then upwards again through I (fig. 498), in such a way as to yield the greatest amount of warmth. The smoke-flues K (figs. 495, 496, and 498) are placed on the uppermost part of the radiators, and lead to the front of the heating-chamber, whence they are conducted to the chimney-flue. The doors L, M, and N serve for feeding the Calorifer, for cleaning out the grate, and for removing the ashes. They are made to be air-tight when closed, and remain closed whilst the apparatus is in action. The covers O (figs. 497 and 498) are for cleaning out the radiators. The warm air is kept sufficiently moist by an evaporating vessel P (figs 495 and 496), which projects through the front partition above the Calorifer, and is provided with an indicator. The front of the apparatus is made of strong sheet-iron, and part of it can easily be removed for the purpose of cleaning the radiators, or for repairs. No brickwork has ever to be disturbed. The calorifers are made in various sizes, and their heating capacity is based upon the calculation of heating from 20° F. external temperature.

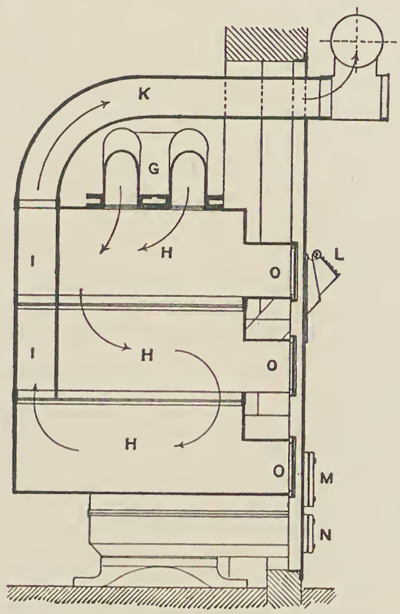


Fig. 498.—Vertical Section through Radiator of Calorifer.

This apparatus is intended to be set in a brick chamber, placed in direct communication with the external air. Some filtering material, such as muslin, can be stretched across the opening, and the heated air passes up the special flues, which must be provided in the building in the same way as for the Smead system. The Heim system differs, however, from that system in having the inlet at a height of about 6 feet above the floor, and in providing two outlet valves into a common flue, one valve being near the floor for winter use, and the other near the ceiling for summer use. A valve is provided in each inlet-flue, by means of which any desired mixture of cold and hot air can be obtained. It will be seen that here there is an attempt to humidify the air, which, I consider, should always be done. In the special pamphlet published by the

makers, reference is made to the fact that the Heim apparatus has been fitted in a number of Austrian royal castles. It is, in my opinion, very desirable (if the valves are only arranged to be either full open or quite shut) that some arrangement should be made for connecting the two outlet-valves together, so that one or other must always be open and the other shut; but if each valve can be regulated for partial or full opening, then that is obviously impossible, and the upper valve should be locked during the winter, and the lower one locked during the summer, otherwise both valves may be left open at the same time, when the ventilation will be imperfect and currents will be set up in various directions.

I have already described the Smead system, which is so well known in the United States, and also a characteristic continental system; it will now be of interest to see how **the same problem has been treated by a British engineer,** Mr. Key, and to note the radical differences between the systems. One of the objections raised to the Smead system by Drs. Drysdale and Hayward, and also by others, was that the direction of the currents of heated air in the rooms was such as to cause the vitiated air to be breathed over again. The objection has not perhaps much force when gas is not being burnt, for it is the practice of the Smead Company in the United States to change the air in schoolrooms about six times per hour, and to provide from 1500 to 1800 cubic feet per head.

The Key system is what is known as **the plenum method of warming and ventilation.** The inventor early realized that the external air is so charged with soot, dust, and fog, that it is absolutely necessary to clean it thoroughly before it is admitted into a building; he also found that a dry cloth screen is of little use for the purpose, as it allows the particles to pass through it after a time, and becomes coated with dirt, which in itself may become a source of danger. He thus describes his system. "The air-supply for a building is drawn, by means of an air-propeller or fan, from a point where it is of undoubted purity, and furthest from any possibility of contamination. The entering air passes through an outer warming coil, and then through the air-filtering, air-washing, and humidifying screen. It is then warmed by coming into contact with coils, clustered in batteries within the air-warming chamber. The air passing through this chamber can be instantly reduced in temperature by admitting filtered cold air, through the by-pass doors provided for the purpose, the warm and cold air mixing while passing through the air-propeller. The air is then propelled into the main air-ducts, from which it passes into flues leading to each room. Secondary air-warming coils are placed at the base of each flue, so that the air

to each room may be warmed to any desired temperature while passing through them, and independently of the others.

"The volume of air admitted to each room is directed towards the ceiling, and can be regulated, or shut off altogether. It enters under a slight pressure, and is therefore continuously forcing out the air previously within the room. This may be done at a rate to renew the air of a room from 6 to 15 times per hour, and without experiencing [it is said] the slightest draught. The outgoing air passes off at the floor-level, and is led to roof ventilators, where the outlet air-valves are so constructed as to place the whole air within the building under a slight pressure of about four ounces per square foot in excess of the outside atmospheric pressure at the time. Whether there be no air movement outside, or whether it be blowing a gale, the outgoing air [we are told] flows in a continuous stream, unaffected by calms or gales."

The apparatus for filtering and washing the air consists of several thousand cords of suitable material, stretched from a beam near the ceiling to another near the floor of the air-chamber. When finished, the screen has the appearance of coarse cloth stretched across the apartment. The cords are placed so close that they touch each other; copper wires are laced through the vertical cords in horizontal rows, and being drawn tight, give the screen a flat surface. The rough fibrous nature of the material breaks up the entering air into very minute streams, which pass through equally all over its surface. These screens may, if desired, be formed double, in order to give an extra cleansing or scrubbing surface. The screen is kept moist by water trickling down each cord; and at regular intervals of more or less frequency, an automatic flushing-tank discharges a considerable volume of water down the screen, to remove loose matter which may have collected, and to thoroughly wet the whole surface.

Reference has already been made to the necessity for very careful attention to **the humidity of the air** used for warming, and it will be seen that the temperature of the incoming air, in this system, is first raised, then washed and humidified by the screen, and afterwards further heated by the local coils. It is warmed to a temperature of about 57° F. in passing through the primary air-warming chamber, and no portion of the air is raised above this temperature by contact with the heated coils. Either hot water or steam may be used in the pipes as the heating medium, but the inventor appears to prefer to use steam, as, of course, a somewhat smaller exposed surface will suffice, while at the same time none of the air is "burnt". One of the minor defects of the system appears to me to be the difficulty or impossibility of regulating the degree of humidity given to the air, as the quantity of water passing over the screen is practically constant.

With regard to the general system of **admitting the fresh air at the ceiling,** and discharging the foul air at the floor-level, it may be said that the wisdom of this course depends largely upon the method of illumination. If coal-gas is burnt for illumination in the ordinary way freely in the air, the heated products of combustion naturally rise to the ceiling, and should, in my opinion, be removed thence. Where the outlet-holes are at the floor-level, the products of combustion (including carbonic acid gas, CO_2) must pass down and be breathed. For this reason, I am opposed to the downward system of warming and ventilation in such cases. Of course, if electric lighting be employed, no foul gases are produced by the lighting, and the objection would not hold; there is, however, a certain very small amount of heat produced by the lamps, which would have some little effect in producing or assisting upward currents of air.

Having now dealt with some of the methods adopted for passing warm air in large volumes into the rooms of buildings, as the sole means of warming and ventilation, I shall draw attention to a combined system, devised by Drs. Drysdale and Hayward, in which use is made of **warmed air in conjunction with open fires.** This system is described in their work entitled *Health and Comfort in House Building.* It is an axiom that change of air in a room is essential for health, and consequently that both an inlet and outlet for air must be provided; but no direct admission of cold external air into rooms should be tolerated. Moderately impure air, as pointed out by Dr. Inman, may not be so injurious as a draught of cold air. If the open fire is used, with a separate direct supply of fresh air from outside, this may, and in fact does, check the currents of cold air towards the fireplace, but rather diminishes the value of the ordinary chimney for ventilation. The fireplace should be studied with a view to economy of fuel, and not as a contrivance for the ventilation of rooms.

Drs. Drysdale and Hayward point out that no system of single-room ventilation and warming can be satisfactory, and that a general system is needed; they recommend the use of the kitchen fire as the means of causing the requisite suction, unless a special fire be set apart for the purpose. They also point out that the system of general diffusion of warmth throughout the house does not conduce to effeminate habits, or tend to induce a habit of avoiding exercise in the fresh air, but, on the contrary, is likely to diminish the tendency to bronchitis and quinsy. Supposing, say the authors, that we have provided for the ingress of a sufficient supply of moderately-warmed fresh air for all the wants of the house, and for a sufficient suction to draw off the vitiated air, the next point is to see that this heat is not wasted, and unless special care be taken in the original plan of the house, this waste will occur. As soon as the front door is

opened, the cold air from outside rushes in, and enters the hall, which, as a rule, passes between two sets of rooms direct to the main staircase, and the cold blast rushes through the whole house, tending to reduce it to the temperature of the outer air; the usual plan of an inner door is not always effective, as the outer door is often left open. The back door should open into the scullery or kitchen, or some other room where it is the interest of the servants to keep the door shut; the front door should open into a lobby or vestibule, to which the servants have separate access without going through the central hall of the house; and the windows, they say, should be made fast. The authors are no advocates of warming the house by heated air; all they recommend is the warming of the incoming air needed for ventilation, and this, unless the velocity is great, need not be heated above 65° F. for the comfortable supply of rooms otherwise warmed. It appears that Dr. Gordon Hogg had a house built at Chiswick, in which the authors' plans were carried out, except that no fires were used; within a year or two, however, fireplaces were added, and the windows made to open.[1]

Drs. Drysdale and Hayward consider that the best way of warming is by passing air over hot-water pipes, as this plan avoids burning the air. Two different houses are described. In house No. 1, there are no passages, and the incoming air is warmed by being passed over pipes heated by hot water at low pressure; in the case of the house No. 2, the same result is obtained by the use of small pipes with high-pressure hot water. The authors lay no stress upon the particular means adopted for warming the air, except that they consider that it should be done by surfaces at comparatively low temperature, and not by highly-heated surfaces as in a stove. The humidity of the air is a most important question, and it will not be satisfactory to merely heat the incoming air without paying any attention to its hygrometric condition. Air at 66° F. will hold about 6 grains of water suspended in each cubic foot, while air at 30° F. will only hold 2 grains of water in suspension. I have already pointed out the great objection to passing the air over highly-heated surfaces, as the contact burns and decomposes the particles of dust and organic matter, which are constantly present in the air, thus rendering it unpleasant for breathing.

The authors state that **the primary inlet for the air-supply** to the whole house should be in the basement, or perhaps it would be better to have such an inlet on each side of the building in order to be able to take advantage of the winds; or, to avoid dust and dirt, the inlet might consist of a flue carried up to a point above the roof, where it would be provided with an opening on each of

[1] Drawings of this house appear in Plates XX. and XXI., and a drawing of a somewhat similar house in Plate XXII. Further remarks on the system will be found at the end of Section XI.—Ed.

four sides. The incoming air may be screened, washed, cooled, or perfumed according to taste, but it must always be borne in mind that the screening and cleaning operations afford great obstruction to the passage of the air, and it is doubtful, in my opinion, whether the suction of the kitchen-flue would have been so successfully used by the authors, if they had resorted to any of these methods.

They say the best place for the furnace of the warming apparatus is the basement of the stairs lobby, and proceed to describe **the system as applied to the two houses** before alluded to, the kitchen fire alone being used as a means for creating the necessary suction. House No. 2 had a central corridor upon each floor, and these were warmed in the following manner:—The warm air was first led into the ground-floor corridor, from which it passed up through a wide grating fixed in the middle of the ceiling; the air passed through between the ceiling and the floor above, and into the corridor above by a grating at each side running near the wall, as in fig. 499, thence it passed similarly to the corridor above. These corridors thus became sources of warmed air, and the rooms on each side were fed from them by a series of holes, 7 inches long and 5 inches wide, formed in the cornice at the ceiling-level; the shape of the inlets is shown in section in fig. 500, and as many were used as could be got in the length of the rooms. The vitiated air was taken off by similar orifices in the cornice at the opposite side of the room, and it was found desirable to avoid the resistance entailed by causing the current to pass at right angles to its previous direction; to obtain the desired result, the orifices were formed with an easy curve, as shown in fig. 501, the form approximating as nearly as possible to the Schiele curve. The fireplace should if possible be at the side of the room opposite to the inlet of air, and, if convenient, the lower member of the cornice should be hollow for its entire length, and the opening into the room be protected with an ornamental grating.

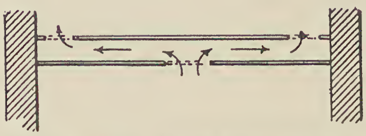


Fig. 499.—Section through Floor of Corridor, showing Passage of Heated Air.

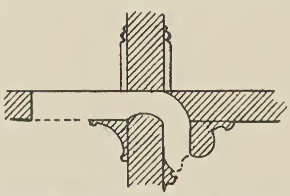


Fig. 500.—Section showing Air-inlet from Corridor to Room.

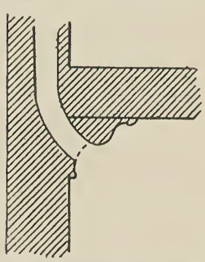


Fig. 501.—Section showing Air-outlet from Room.

The air is let into the rooms at about 65° F., and the authors remark that, when there are living beings in the room, their bodies are at 98° F., and the vitiated air ascends and the incoming warm air descends. Though carbonic acid gas is heavier than air at the same temperature, they consider that there is no danger of its settling near the floor, because

of its small proportion, and the speedy diffusion which takes place between gases.

The flues must of course be as smooth as possible inside, in order to afford the least obstruction to the passage of the air. Each room must be provided with **a separate outlet-flue,** and this must lead direct into a foul-air chamber at the top of the house; all the foul-air flues must come into this chamber at the same level. The foul-air chamber itself was in this case constructed of zinc, and was perfectly air-tight; from the base of this chamber descends the main foul-air flue, and this should go direct to the base of the kitchen-flues. All the passages should be so designed that the velocity of the air travelling along them should not exceed 150 to 200 feet per minute. The authors discuss various methods of creating the necessary suction to get rid of the foul air, but conclude that the kitchen-chimney is the best. The upcast foul-air flue must be separated from the back of the kitchen-fire by a sufficient thickness of fire-brick, and the smoke-flue should preferably be of iron, so that as much heat as possible should be given off to the foul-air flue. They propose that the kitchen smoke-flue should be fixed in the centre of the square foul-air upcast shaft, and that the top of the opening of the smoke-flue should be restricted to 9 inches diameter, which they consider ample, after carefully experimenting upon the subject. If, after trial, the heat evolved by the kitchen-fire is found inadequate, then a few coils of Perkins's hot-water pipes, or some jets of gas, might be added. They have, however, found that in houses of moderate size, the kitchen-fire suffices. The cross areas of the upcast shafts taken together should exceed the cross area of the downcast shaft, and there should be a special valve for regulating the size of the outlet for each room separately. From experiment upon the two houses already alluded to, the authors found that the velocity of air in the upcast shaft was about 400 feet per minute.

In cases where the houses are already built, it may be impossible to use the kitchen-flue as an upcast shaft; it would then be advisable to use gas-jets close to the outlets of each of the rooms, and probably a ring of gas-jets at the top in the foul-air chamber. While the problem of warming and ventilation may have been satisfactorily dealt with by the authors for special cases, it must always be remembered that the two houses referred to were specially designed for the system described, and such a system is not easily applicable to houses already built, with the front and back doors both possibly opening into the main hall or corridor, and both in direct communication with the central staircase.

In the country, the air is usually sufficiently clean to be admitted without filtration, but in towns it is so **loaded with soot and dust,** that some method of

cleansing it is eminently desirable. As soon, however, as filtration is resorted to, considerable resistance will have to be overcome, and I consider that in many cases it will be necessary to resort to the use of a ventilating fan, if certainty of action is to be secured, but such a fan is quite out of the question in a house of small or moderate size, unless an electric motor be used. The employment of electricity for the purpose would simplify the problem considerably, and would render unnecessary the use of the downcast and upcast flues. It is not desirable, however, to be dependent upon the action of such a fan for the warming and ventilation of an entire house.

CHAPTER V.

HEATING BY HOT WATER.

The subject of heating by hot water may be conveniently divided into two parts—*low-pressure heating* and *high-pressure heating*, which will be dealt with separately, as the arrangements of the various parts of the systems differ considerably. The low-pressure system has found by far the greatest favour in Great Britain, by reason of its greater safety and efficiency. The pipes are, however, larger than in the high-pressure system, and therefore the latter may sometimes be preferable. If the apparatus has been once properly installed, it should require very little attention, and an ordinary domestic servant, without any special training, can easily attend to the small amount of stoking required. The apparatus in either case will consist of a hot-water boiler, heated by a fire, gas, or oil, according to the magnitude of the work to be done, and a system of water-circulation pipes, either themselves giving off the heat, or connected with special groups of heating-surfaces known as radiators. Besides this, in the case of a low-pressure apparatus, a special feeding-cistern and pipe will be required, in order that the whole of the system may be kept full of water. In the high-pressure system, such an arrangement is not necessary.

In comparison with heating by open grates or stoves, the systems of heating by water possess the following advantages:—There is only one central fire to be attended to, and this is usually placed in the basement, entirely out of sight, at a point close to the fuel-store. In this way all dirt and dust from the use of coal and the removal of ashes are kept out of the house proper, or relegated to a place where their presence is not so objectionable. As the fuel

can be usually delivered close to the point where it is to be used, the annoyance and trouble caused by the filling of coal-scuttles, and the transport of coal through the living-rooms, are entirely avoided. The temperature of each room can be regulated to any desired degree, and ventilation can be effected quite as easily as by means of open fires. The radiating surfaces can be placed in the best possible position for giving the desired result, and can at the same time be made to counteract the evil effects of draughts produced by badly-fitting windows, &c. Equable warmth over a whole apartment can be obtained without difficulty. With the low-pressure system there is no danger to children, as they cannot possibly be seriously injured, even if they touch the radiating media, although, of course, it is preferable to protect these where very young children are constantly present. If the radiating surfaces are kept at a relatively low temperature, the passage of the incoming air over them will not deteriorate it, as may be the case where the air is passed over highly-heated surfaces, in contact with gases produced by burning fuel.

The position of radiators is a matter of some importance; they are usually placed in front of the windows, so that an upward current of warmed air may be produced, in the very place whence a cold draught usually proceeds. It is, however, preferable to form a special opening through the wall, directly under the window, and to place the radiator in a special case, through which the incoming air is taken. In this way, only warmed fresh air can enter the apartment, and the vitiated air must then be allowed to pass out by some specially-prepared openings. One of the objections to the use of radiators is that the current of warm air, ascending from the heating-surfaces, carries up with it particles of dust from the atmosphere, and from the floor of the room. After a time, this will cause a large black stain upon the wall. This is an additional reason for placing the radiators in front of the windows. In corridors and places of that kind, where such an arrangement is impossible, a shelf with a bracket at each end should be so arranged as to deflect the currents of heated air out from the wall.

One of the chief objections to hot-water warming-apparatus, is that the appearance of the radiators and pipes is not cheerful; and, in Great Britain at any rate, the cheerfulness of an open fire, though accompanied with inequalities of warming, is preferred before the more equable temperature obtained by the use of radiators.

There is no reason, however, why **a combined system of open fires and hot-water heating** should not be used. The flue of the fireplace might then be used as an outlet for the vitiated air, unless gas or oil is being burnt for the

illumination of the room, in which case I consider it desirable to form the outlets close to the ceiling. There are many instances where a hot-water system of comparatively small size and little cost, might be installed in a house, for the purpose of heating the bedrooms, hall, and corridors, while open fires might be retained as a means of heating the sitting-rooms on the ground-floor. With a very small expenditure of fuel, the sleeping apartments might then be kept at a temperature of 55 degrees during the night; and the labour of stoking would be very little, as special boilers are now made which will burn for twelve hours without attention.

1. *THE LOW-PRESSURE SYSTEM.*

The boiler is perhaps the most important feature in any installation, as upon it depends principally whether the system will be economical in the use of fuel, or very expensive.

The number of types and forms of hot-water boilers is very large, and almost every maker has some special design which he naturally considers superior to all others. In Great Britain, boilers are almost entirely made of wrought-iron or mild steel plates, welded into a solid vessel, but in the United States they are very frequently made of cast-iron. This material, however, is not by any means equal to the others, as it is liable to crack when heated, and thus perhaps let loose a flood of boiling water in the basement of the building.

In boilers which are to be used solely for purposes of heating, it is not so necessary to provide ample **facilities for removing incrustation** as in boilers for the supply of hot-water for domestic purposes. A system of hot-water heating consumes practically no water, it being only requisite to allow a supply of a few pints per week to replace the losses produced by evaporation in the expansion tank. The same water circulates constantly, and, having once deposited its impurities, can cause no further trouble with incrustation, while, in the case of a boiler used for hot-water service, the deposit goes on gradually accumulating in the whole of the interior of the apparatus.

It is always desirable, on the score of economy of fuel, **to set the boiler in brickwork,** as the loss of heat by radiation is far less than when the metal exterior of the boiler is exposed to the air. Of course it costs more to build a brick setting than to merely place the boiler on the floor, and for small installations, where first cost is the most important item, it may be advisable to employ a boiler without setting.

Boilers heated by gas are made for use in connection with low-pressure hot-

water apparatus, and will prove useful for small installations. A good boiler of this kind is shown in fig. 502. It has the disadvantage of being made of cast-iron. The cross tubes are cast with the inner body. This boiler is made in two sizes, the smaller being $19\frac{1}{2}$ inches high and $13\frac{1}{2}$ inches from back to front, while the larger is 31 inches high and 17 inches from back to front. The former is said to heat, as a maximum, 40 feet of 4-inch pipe, and the latter 100 feet. The connections are 1 inch and $1\frac{1}{2}$ inches respectively.

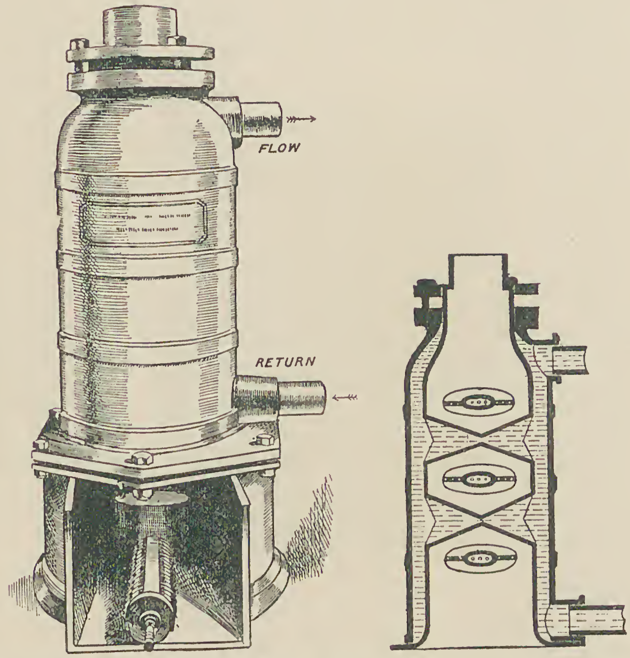
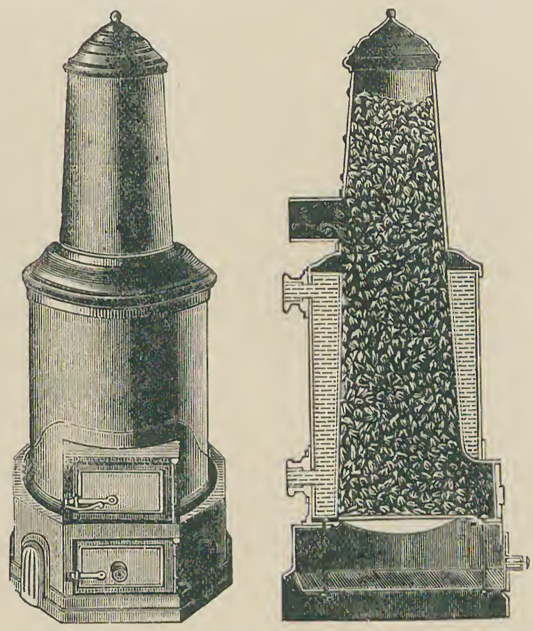


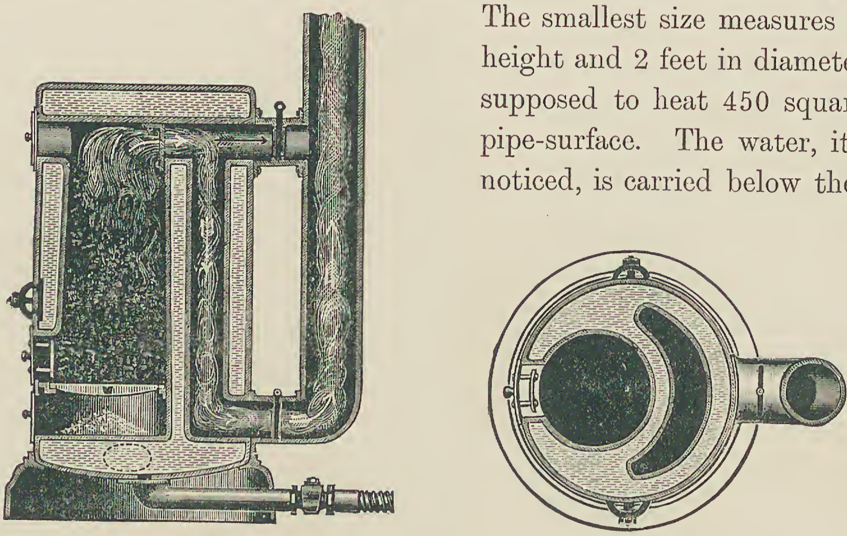
Fig. 502.—View and Section of Fletcher, Russell, & Co.'s Cross-tube Gas Boiler.

Where the amount of pipe to be heated is small, **an independent boiler** of the form illustrated in fig. 503 may be used; this is specially designed so that a large amount of fuel may be fed into it at one time, and the inner part is made conical to prevent the fuel from sticking. Such a boiler would have one 2-inch flow-pipe and one 2-inch return, and would be made of wrought-iron plates welded together. If 4 feet high and 15 inches in diameter, a boiler of this kind will heat about 130 square feet of radiating surface,[1] while one 6 feet high and 24 inches in diameter is estimated to heat about 450 square feet. For a larger installation, such a boiler as the "Marlor", shown in fig. 504, may be used; it


View Section.
Fig. 503.—View and Section of Independent Conical Boiler.

[1] By "radiating surface" is meant the uncovered external surface of the pipes, radiators, coils, &c., connected with the boiler. Those parts of the system which are not required to radiate heat should be carefully protected with some non-conducting covering.

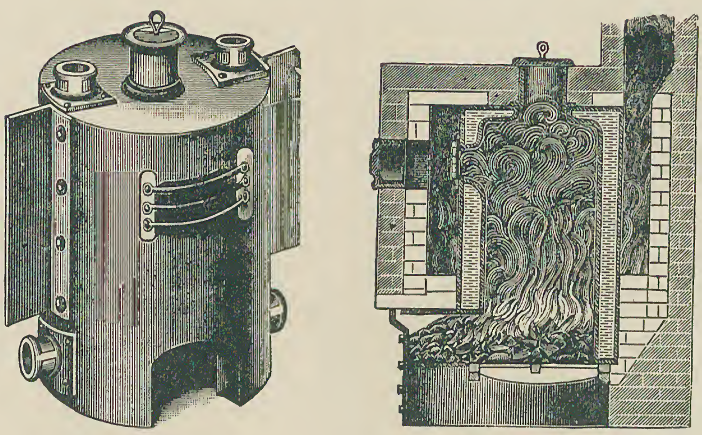
is made of $\frac{3}{8}$-inch mild steel plates, in various sizes up to 6 feet high and 4 feet in diameter, this size being supposed to heat 2500 square feet of pipe-surface. The smallest size measures 3 feet in height and 2 feet in diameter, and is supposed to heat 450 square feet of pipe-surface. The water, it will be noticed, is carried below the level of



Section. Plan.

Fig. 504.—Plan and Section of the "Marlor" Boiler.

the ash-pan, so that there is a quiet place in which sediment may easily collect, and this can be flushed out at intervals. Such a boiler is, however, somewhat expensive when compared with the types already referred to.

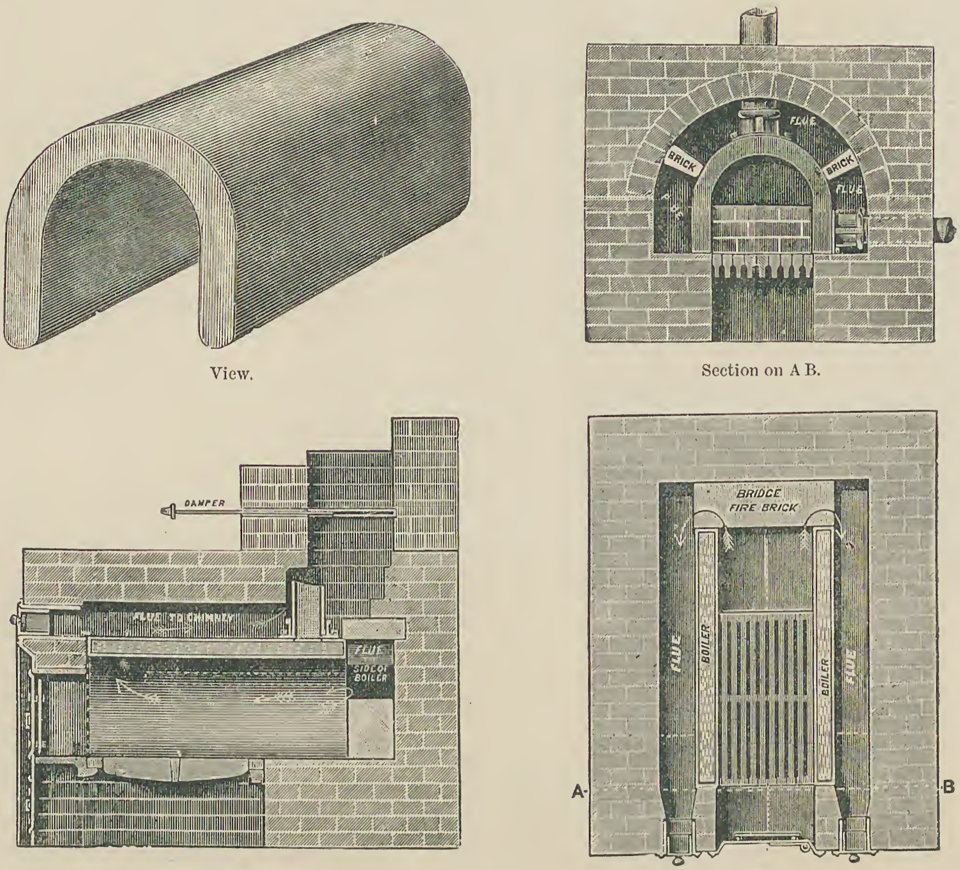


View. Section.

Fig. 505.—View and Section of the "Excelsior" Boiler.

For larger works, it is best to use a type of boiler in brick setting, as much greater economy can thus be obtained. The boiler illustrated in fig. 505 is known as **the "Excelsior" Boiler**, and consists of an external cylinder of wrought iron, into which is welded an inner cylinder of Siemens mild-steel plate. The metal is $\frac{5}{16}$ inch thick, or, for better work, $\frac{3}{8}$-inch. The water-space is brought down to the level of the grate-bar, and the fuel is filled-in through the top hole, and falls on to the grate-bars; the products of combustion rise and fill the inner chamber, then pass out at the front opening (which is protected by cross bars) into the space between the boiler and the brickwork, travel half-way round in

each direction until they strike the baffle-plates, under which they pass, and then proceed round the back of the boiler to the flue. It will thus be seen that the products of combustion surround the water-chamber on all sides. In the illustrations, two connections are shown at the top for the flow-pipes, and two inlets at the bottom for the returns. Such a boiler, measuring 24 inches in height by 18 inches in diameter outside, is capable of heating about 350 square



View. Section on A B.

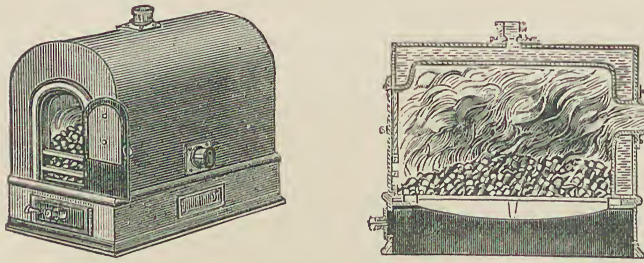
Longitudinal Section. Plan

Fig. 506.—Plan, View, and Sections of Simple Saddle Boiler.

feet of radiating surface, while a boiler 36 inches high by 26 inches in diameter will heat about 825 square feet of radiating surface.

The boiler which has found the greatest favour—owing to its very simple form—is **the plain saddle boiler,** shown in fig. 506. This is made of welded wrought-iron plate, $\frac{5}{16}$ or $\frac{3}{8}$ inch thick, and is so set that the products of combustion play all over its inner and outer surfaces. The plan and sections of the setting show very clearly how this is accomplished. The flames play upon the inner part of the boiler, and the gases then pass to the back, return by the sides

to the front, and pass over the top of the boiler to the flue. The flues on the top of the boiler are not of much use as heating-surfaces, but the heat is radiated off the brick arch; the side flues are of much the greatest efficiency. If coal be burnt in a boiler of this class, the flues should be constantly swept out to maintain the boiler in its highest efficiency. Such a boiler, 48 inches long, by 22 inches by 19 inches over all, is expected to heat about 640 square feet of radiating surface. Saddle boilers can be obtained of smaller size, made in the independent form, that is, to be used without brick setting, as shown in fig. 507. This cannot, of course, be so economical as the others, as the whole of the exterior of the boiler is exposed to the air, and the flames pass direct to the flue. The loss of heat from the exterior could be diminished by coating the boiler with non-conducting composition. The saddle boiler may be made as shown in fig. 508; the return-flue then passes back inside the boiler, and therefore more use is made of the waste gases. The cost of such a boiler is, however, higher.



View. Section.

Fig. 507.—View and Section of Independent Saddle Boiler.

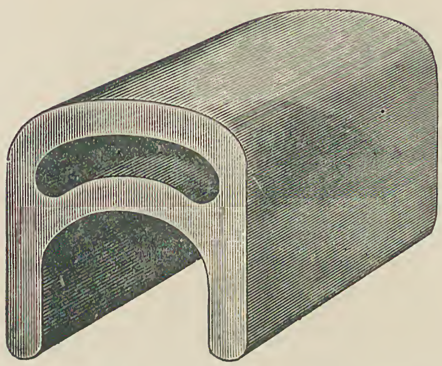
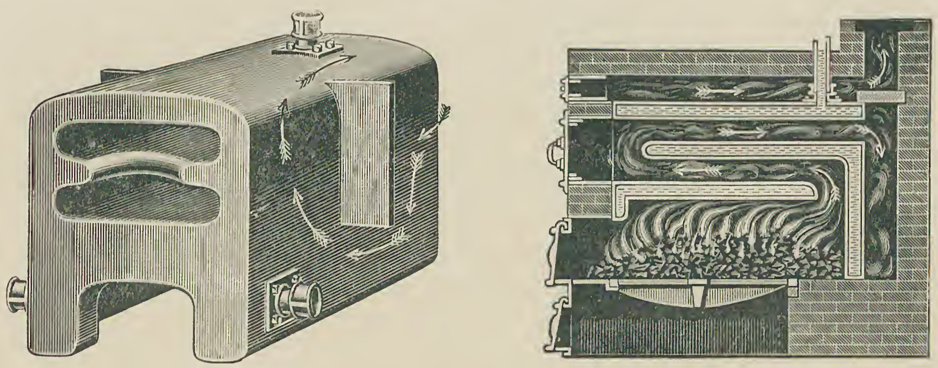


Fig. 508.—View of the "Devona" Saddle Boiler.



View. Section.

Fig. 509.—View and Section of the "Edina" Boiler.

The boiler illustrated in fig. 509 is a comparatively new design, in which the

products of combustion are passed round a great many times before finally reaching the flue. Economy in fuel is obtained, but the first cost of the apparatus is considerably greater than that of a boiler of the plain saddle form.

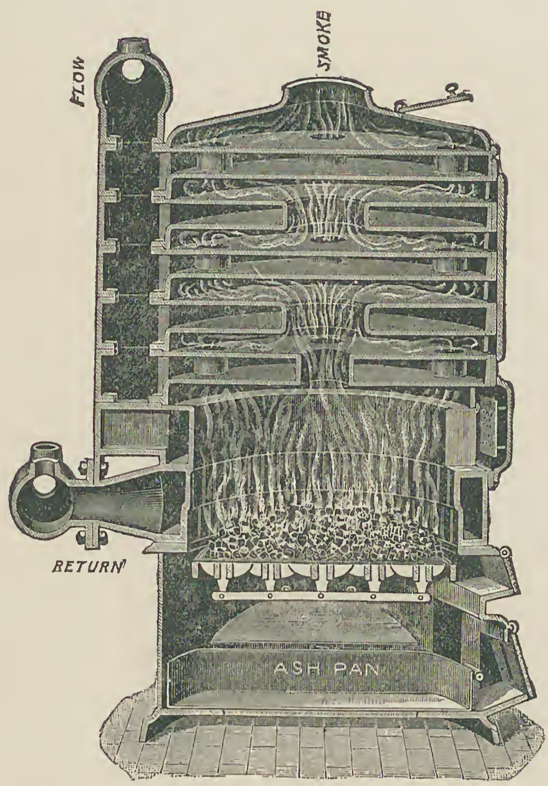


Fig. 510.—Vertical Section of the "Oxford" Cast-iron Boiler.

Cast-iron Boilers.—The Gurney Foundry Co., Ltd., of Toronto, Canada, make two types of boiler. A section of the larger type, known as the "Oxford", is given in fig. 510, and the separate portions of which the apparatus is built in fig. 511. This "heater" is built upon the theory of directed circulation: thus, the water entering at the return heater (which is on the level of the fire-pot instead of in the ash-base) is passed to the front of the fire-pot at the bottom, and over a diaphragm which runs through the water-chamber of the fire-pot, and then back to a point above the point of entry. It is there conducted into the first section above the fire, through two openings, which run continuously from the fire-pot to the top section

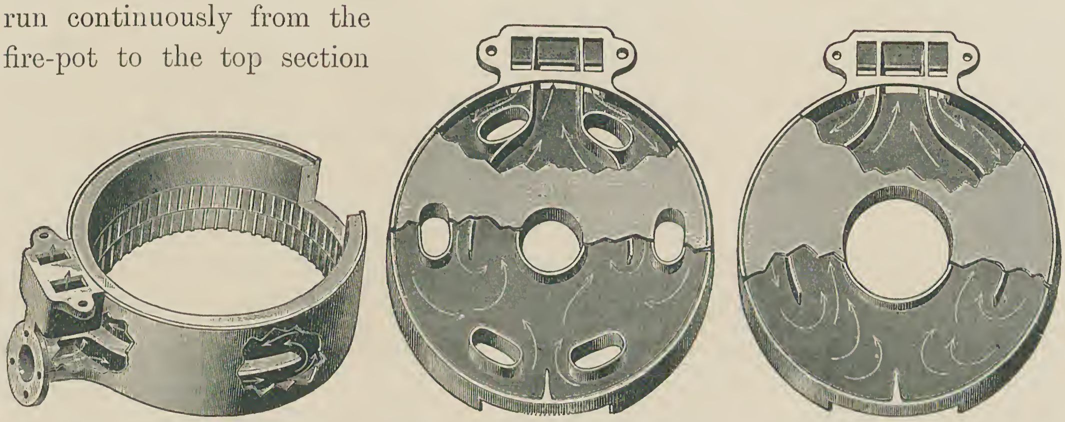


Fig. 511.—View of Fire-pot and two Rings of the "Oxford" Boiler, showing circulation of water and back connection.

of the heater. These two side openings deliver the water on the respective sides of each section of the heater to a chamber which runs to the centre,

to a directing diaphragm, and the two streams are thence thrown back again to a central opening, which is open to the top of the heater, and upon which the flow-heater is placed. The circulation in each of these sections is independent of the other. The theory is, that, while there is no doubt that a directed current over a warm plate is only heated on its outer edges, the agitation and interior circulation in the liquid itself present many surfaces during the time the liquid is passing over the heated surface.

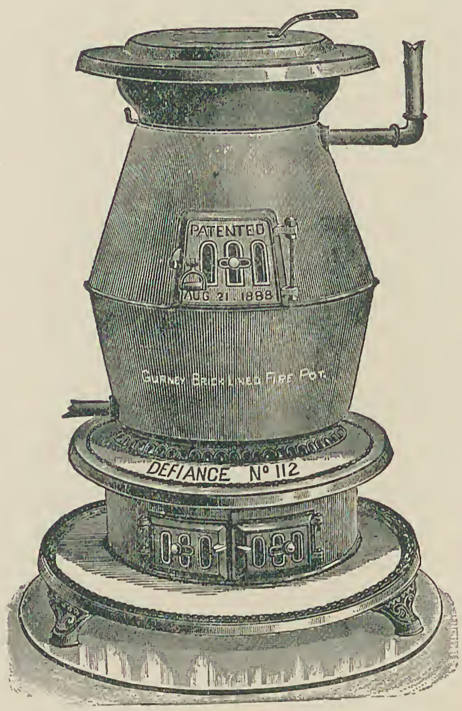


Fig. 512.—View of the "Defiance" Cast-iron Boiler.

At first sight the heater seems somewhat complicated, but it appears to give extremely good results. There will, of course, be loss of heat from the exterior, and this cannot well be counteracted by the application of non-conducting composition, as it would interfere with the joints. A boiler of this kind, measuring $42\frac{1}{2}$ inches in height and 22 inches in diameter, is rated to be capable of heating about 170 square feet of radiating surface, and as this is the rating used in Canada, it is considered well within the mark for the much more temperate climate of the British Isles.

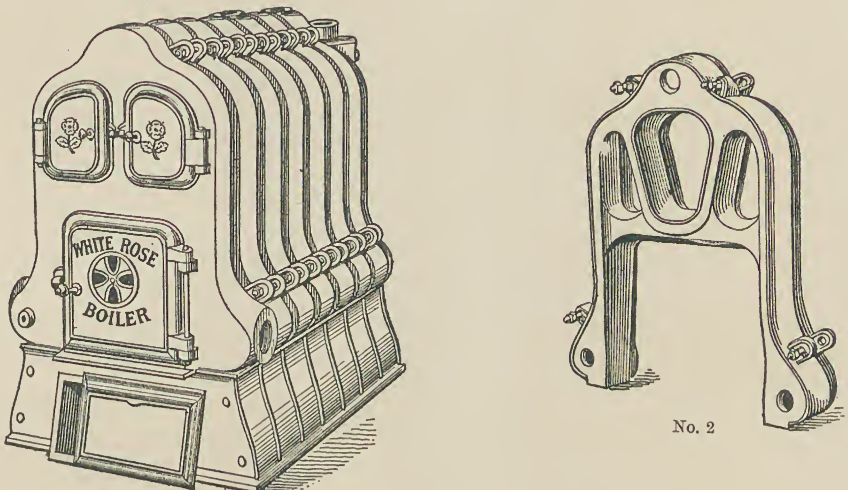
The Defiance Boiler (fig. 512), by the same makers, is intended for small powers.

The "White Rose" Boiler (fig. 513), made by Messrs. Hartley & Sugden, is a cast-iron boiler with the sections arranged vertically and bolted together. It has been extensively used, and is made in a great number of sizes.

The boilers made by Mr. James Keith are also of cast-iron. The type known as **the "Viaduct" Boiler** is illustrated in fig. 514. These require no brick-setting whatever, the cast-iron exterior has a fire-brick lining, which is, in my opinion, a distinct advantage over the Canadian form, as the heat will be radiated from the glowing surface, and it is practically impossible for the exterior of the heater to become red-hot, as may easily happen in the case of the Canadian type. The shell is made in two pieces, which are held together by bolts. The stoking-door is immediately under the crown of the arched water-way, and consequently a large amount of fuel can be inserted, and the fire will burn for a long time without attention. A clinker-door

is provided immediately over the grate-bars, and an ash-door below. There are in the figure two outlets for the flow-pipes, and two inlets for the returns. This type is made in sizes with heating capacities up to 1500 square feet of radiating surface.

The surface required in an ordinary house will not usually exceed this figure, but if it does, another more powerful boiler by the same maker may be used; it is known as **the "Challenge" Boiler,** and is illustrated in fig. 515. This boiler has horizontal or nearly horizontal sections, somewhat similar to the Gurney boiler, but, instead of horizontal baffle-plates, cross tubes run from back to front.



No. 1 No. 2

Fig. 513.—The "White Rose" Cast-iron Boiler
No. 1, View; No. 2, Middle Section showing Flues.

It does not appear to me to be designed so as to baffle the upward currents of heated gases as effectually as the Canadian type, but the deposition of soot upon horizontal surfaces must always be very considerable, even when the boiler is cleaned out frequently, and this would detract from the value of the Gurney boiler.

In order to avoid loss of heat from the external surface of these and other independent boilers it is desirable to coat them thickly with some good **insulating material** such as asbestos, magnesia, or fossil-meal. The material is applied in its plastic state while the boiler is hot, and it is desirable to put on the first coat roughly, then to fix wire netting or some similar support which will form a key for subsequent coats, and so hold the covering in position and prevent it cracking off. The surface of the covering should then be well painted, or canvas may be fixed first and then painted. All the main pipes in the base-

ment should be covered in the same way in order to economize fuel. It is usual to employ coke as the fuel, and the fire can easily be banked up at night.

An interesting type of boiler, resembling the boilers used for high-pressure hot-water heating, is made by Messrs. Renton Gibbs & Co., Ltd., and is

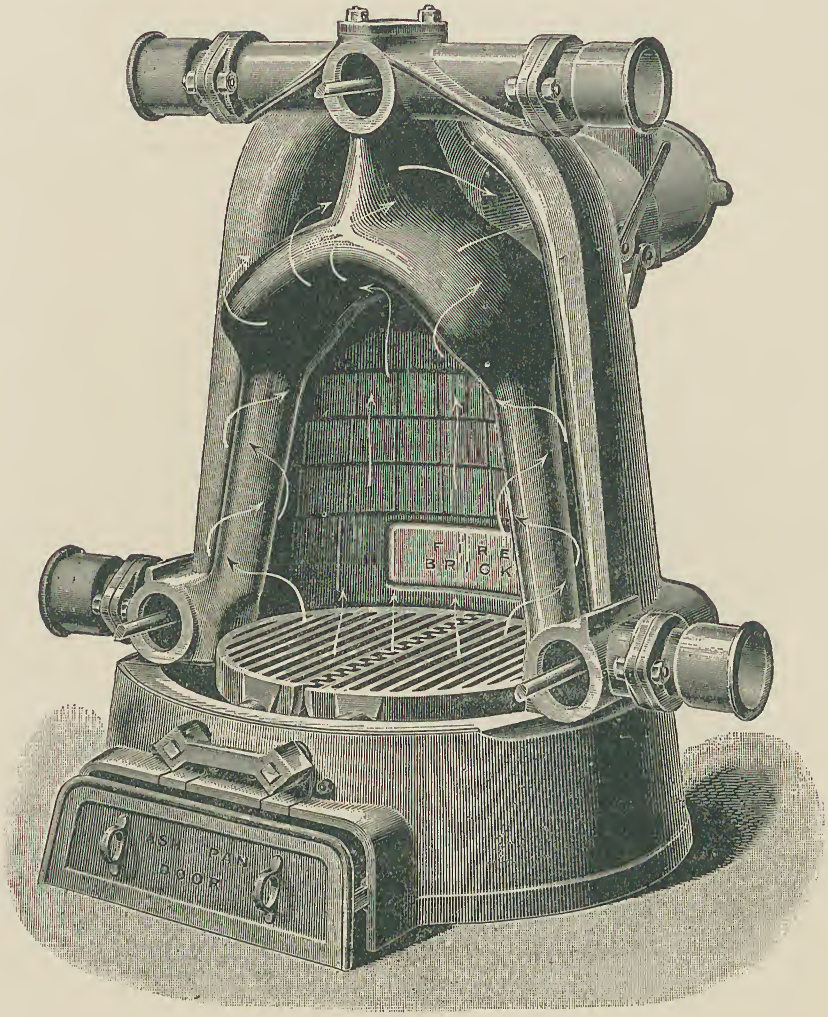


Fig. 514.—View of "Viaduct" Cast-iron Boiler, with the Front Half of the Outer Case Removed.

illustrated in fig. 516. It will be observed that the boiler really consists of a series of coils of pipe, placed in a fire-brick chamber; part of the tubes form the grate-bars, and the flame plays directly on to the upper tubes. The flow of water produced in the tubes is, of course, extremely rapid.

Körting's Boiler is shown in figs. 517 and 518. It is designed for low-pressure steam heating, but we describe it here, as a very similar type is also used for hot-water heating. The following description is taken from the maker's list.

"As the boiler is provided with an open stand-pipe ST, there is absolutely no risk of explosion,[1] and the position occupied by the boiler may be decided without reference to the question of safety. As furnace, which serves at the same time as hopper and as fire-grate, we have adopted our patent cast-iron ring tubes (see D, fig. 518), which are filled with water, and are connected at the bottom and top to the water space of the boiler. By removing the cover F on the top of the boiler, the hopper and furnace may be filled with fuel. It is preferable that, where possible, coke or anthracite coal should be used. The air for combustion passes through the draught-regulator, and a flue in the setting of the boiler, to the front of the furnace. As the furnace-door is kept closed, except when the ash is removed, and with closed door the connection between the front of the furnace and the ash-pit is hermetically sealed, the air on its way to the boiler must pass between the water-tubes of the grate, and through the fuel inside the grate. When the furnace-door is opened for the removal of ash, cold air passes direct through the ash-pit to the boiler, checking the draught, and diminishing rather than increasing the combustion in the furnace during the time the door is open.

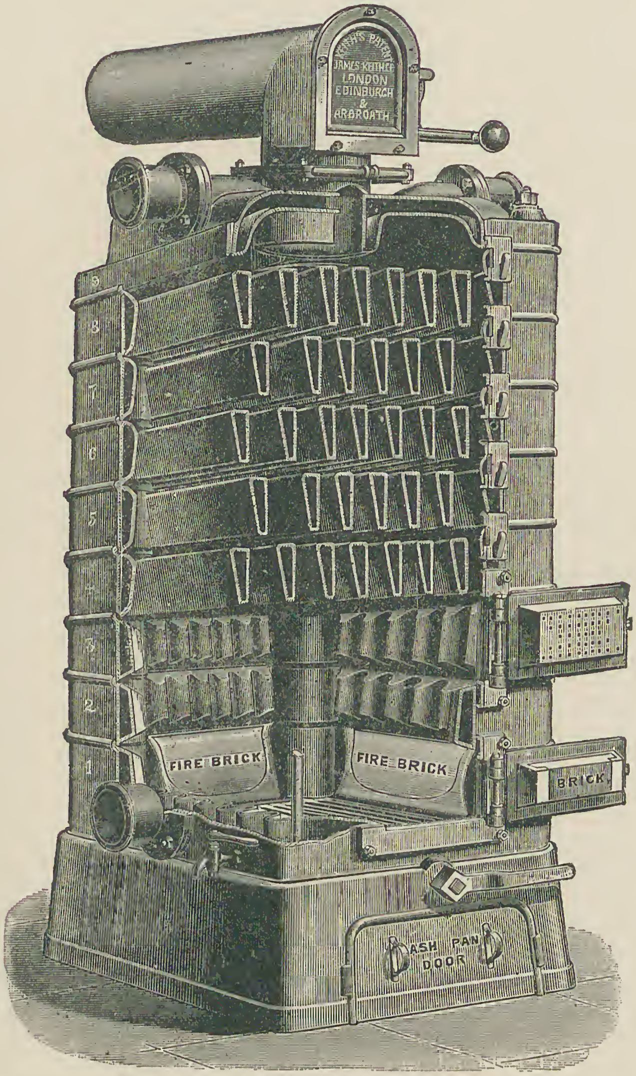


Fig. 515.—Sectional View of the "Challenge" Cast-iron Boiler.

[1] But suppose that the water in this is frozen (as may readily happen if the apparatus is only used on certain days of the week), and the water in the circulation-pipes is also frozen, so that relief cannot be obtained through the air-pipes, then an explosion will be almost a matter of certainty if the fire is lit.—ED.

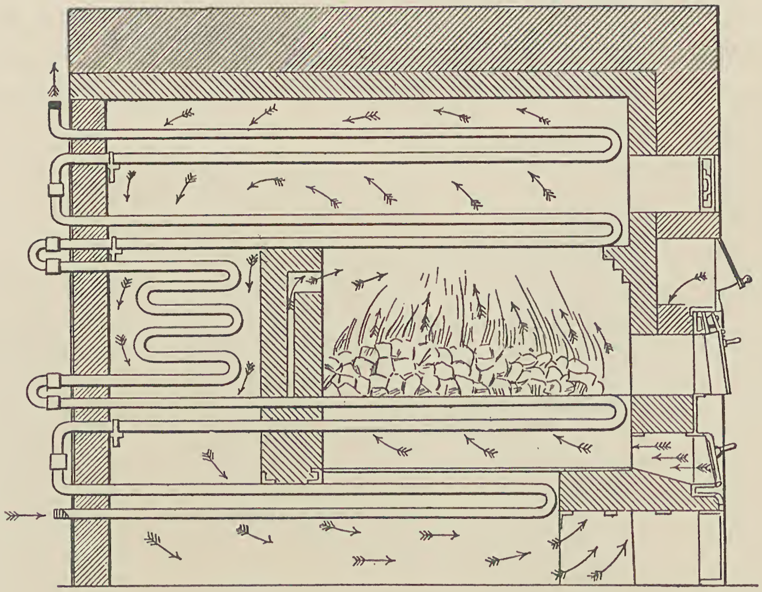


Fig. 516.—Section of the "Renton Gibbs" Tubular Boiler.

The danger is thus obviated that the combustion should be too intense if the furnace-door is inadvertently left open.

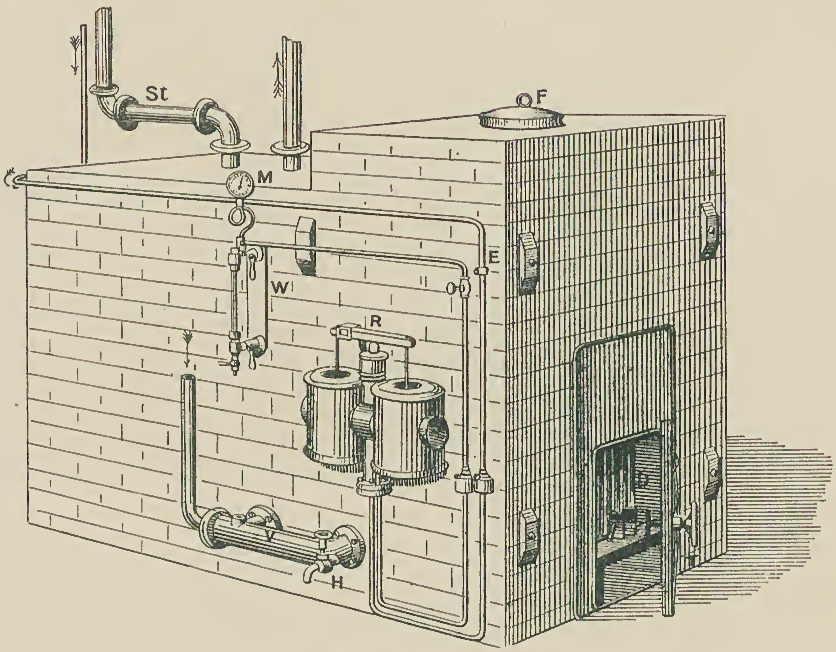


Fig. 517.—View of Exterior of Körting's Boiler.

T, furnace-door; D, patent grate; F, fuel-hopper; R, draught-regulator; M, pressure-gauge. W, water-gauge; H, draw-off cock; V, connection of boiler with water-tube grate, and condensed-water return-pipe; ST, stand-pipe, 16 feet high; E, valve for clearing safety-pipe of water.

"The advantages of the arrangements for firing, as roughly sketched, are

that the combustion of the fuel is exceedingly perfect, and the generation of smoke so small that the problem of smoke-prevention is fully solved; the fuel, which is contained inside the water-tubes, has no direct contact with the brick-work, and repairing or renewal of the boiler-setting is rendered almost unnecessary; and lastly, accumulation of clinker does not form, as the hot clinker suddenly contracts on coming in contact with the comparatively cool surface of

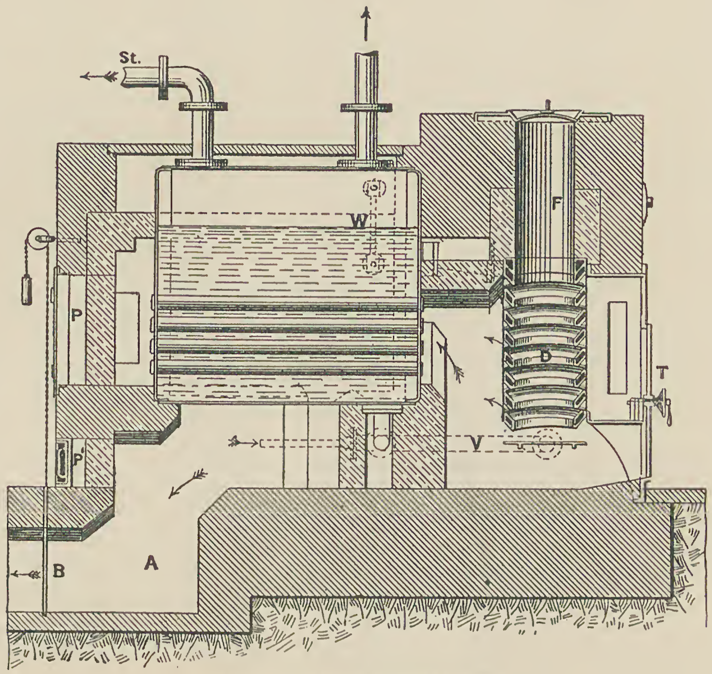


Fig. 518.—Section of Körting's Boiler.

the water-tubes, breaking into small pieces, which readily find their way into the ash-pit.

"The filling-hopper F can be made of any size to suit the kind of fuel in use, and may be sufficiently large to contain two days' supply of fuel. We are making these boilers in ten sizes of from 40 to 400 square feet of heating-surface, and are prepared to make larger ones if required. The attendance required for one of these large boilers is naturally much less than is needed in other systems of heating, where several smaller boilers are used. The work of the attendant is confined to re-filling the hopper F with fuel, which is only necessary at long intervals, and to removing clinker and ash two or three times a day, so that we may claim to have reduced the attendance to a minimum.

"The maintenance of a constant pressure is of special importance with low-pressure steam heating, and we have designed an **Automatic Draught-regulator**

(shown in section in fig. 519) by which this is perfectly secured." This apparatus will be more particularly described in the chapter on heating by steam.

Lack of space prevents detailed description of every kind of boiler, but probably sufficient has been said to give the reader some idea of the principal types now in use. We must now pass to the consideration of another and most important part of a hot-water apparatus, namely, the radiator.

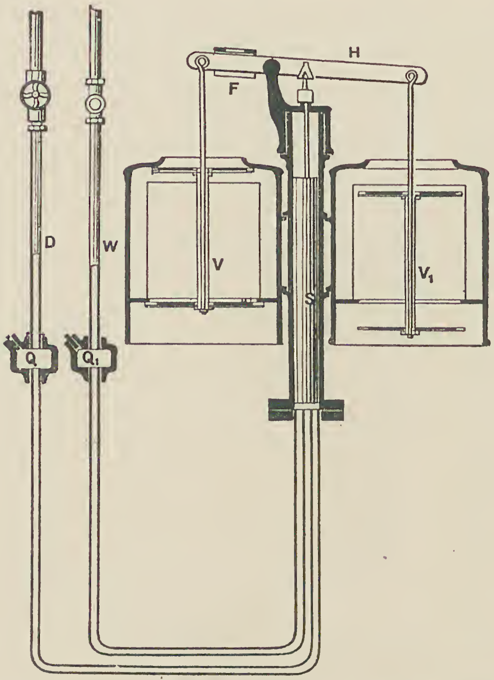


Fig. 519.—Section of Körting's Automatic Draught-regulator.

Q Q_1, vessels containing mercury; D, steam-connection to boiler; W, water-connection to stand-pipe; S, float; H, lever-arm; F, movable weight; V V_1, valves for regulating the admission of air.

Radiators can generally be used either with low-pressure hot water or low-pressure steam; the subject will be best treated here, and need not be referred to in subsequent chapters.

The simplest form of radiating-surface consists of **a straight length of pipe,** which may be, of course, either wrought-iron or cast-iron. Where appearance is no object—as possibly in the basements of buildings and servants' bedrooms—cast-iron pipes are perfectly suitable, and the method of arranging them is shown in plan in fig. 520. The pipes may be two, three, or four inches in diameter, and made with plain socketed joints, or with special joints as shown in fig. 521. The latter is known as Richardson's expansion-joint, and possesses several distinct advantages. The joint is held together by bolts, and an india-rubber washer is put between the two ends of the pipe. If a length of pipe requires to be shortened, the socket end is cut off, and its place taken by a loose flange, held securely in position by a toothed gland, which grips the pipe and prevents slipping. This type of pipe is somewhat more expensive in first cost than the ordinary socketed variety, but the great facility with which joints can be made renders it little more expensive

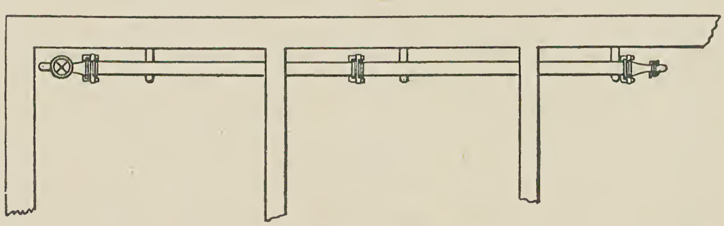


Fig. 520.—Plan of Hot-water Pipe

when fixed. Straight pipes require to be held either above the floor on small stools, which should be provided with rollers (to allow of expansion) of the form shown in fig. 522, or they should be supported on wall-brackets as shown in fig. 523, or hung by slings from wall-

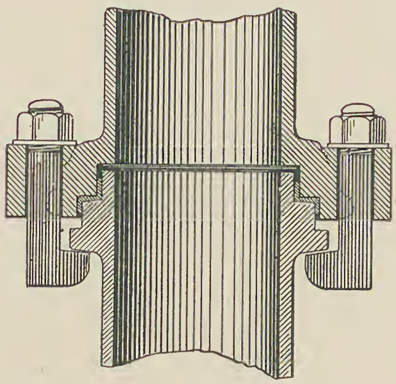


Fig. 521.—Section of Richardson's India-rubber Expansion-joint.

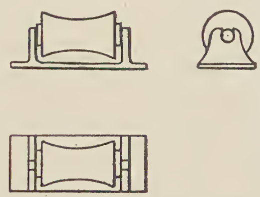


Fig. 522.—Front and End Elevations and Plan of Roller Stool for Pipes.

brackets as shown in fig. 524. They may, however, be supported on simple brackets of T-iron, bent into the form of a hook, and let into the wall, as

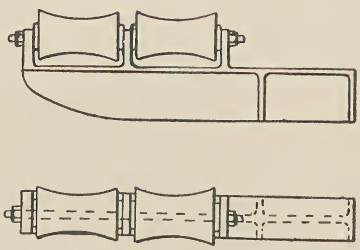


Fig. 523.—Elevation and Plan of Roller Bracket for Pipes.

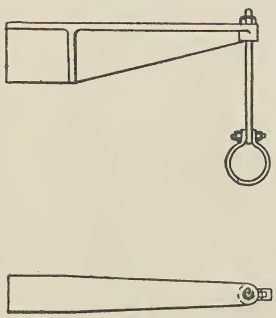


Fig. 524.—Elevation and Plan of Bracket and Sling for Pipes.

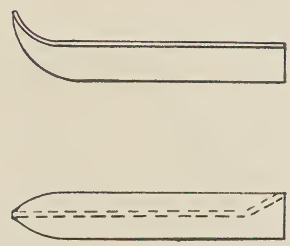


Fig. 525.—Elevation and Plan of T-iron Bracket for Pipes.

shown in fig. 525, and this arrangement is quite sufficient where the lengths of pipe are not very considerable.

There are many cases where pipes of this character would be an eyesore if carried above the floor, but there is a system of placing the pipes in a specially-formed **trench covered with a metal grating.** There are great objections to this system, as the trench forms a most convenient receptacle for dirt and dust and the sweepings of the floors, and, while harbouring vermin, may be the source of infection. This system is shown in the right-hand part of the ground-floor in fig. 526.

If the pipes are carried round the rooms in a **channel formed behind the skirting-board,** and protected by a metal grating, there is not so great an objection; this method is shown in the left-hand part of the ground-floor in

fig. 526 and also in 527. The channel above the floor, however, entails certain difficulties, as the pipes cannot well be carried below the doors, as in that case a dip would be formed, which might interfere with the circulation. In order to avoid the difficulties specified, it is found usually more convenient to place the main pipes between the floor of the room to be heated and the ceiling of the room below. These pipes are preferably carried in a special trench covered with a screwed board, so that access may be obtained to them. If the pipes are thus carried below the floor, it is merely necessary to bring from the main loop short branches to form the inlet and outlet of any particular radiator.

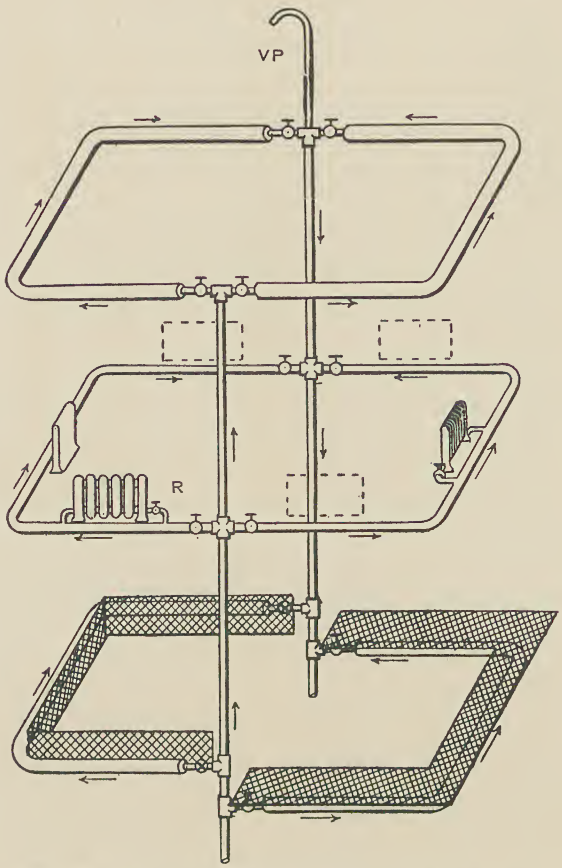


Fig. 526.—Diagrammatic View of Low-pressure Hot-water Pipes R, radiator; VP, vent-pipe.

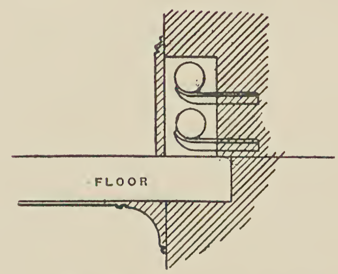


Fig. 527.—Pipes in Channel formed in Wall.

It is preferable to clothe the whole of the pipes where they are not needed for radiating heat, with some **non-conducting material,** such as slag wool, asbestos, magnesia, &c.

Formerly **a very common type of radiator** consisted of two vertical "ends", connected together by a number of horizontal tubes. These coils were usually set close against the wall, but in certain cases were fixed in the middle of entrance-halls, landings, and places of that nature.

These coils have now been practically superseded by **a type having vertical loops,** fastened together in groups of convenient size. The loops are made of different sizes, double, treble, quadruple, &c., and of different lengths. The end

loops are usually provided with feet, and the several parts are shown in fig. 528, which represents a type of radiator known as the Safford; it is manufactured in Canada. A similar radiator is made by Mr. Keith, who has previously been alluded to. In this, each intermediate loop is an exact duplicate of the other, one side of each boss being tapped with a right-hand thread, and the other with a left-hand thread. The loops are then connected together by means of left and right nipples. In some cases the faces of the bosses are carefully machined, so that no packing other than red-lead cement is needed in order to make a tight joint, and in others a washer of paper soaked in boiled oil is employed.

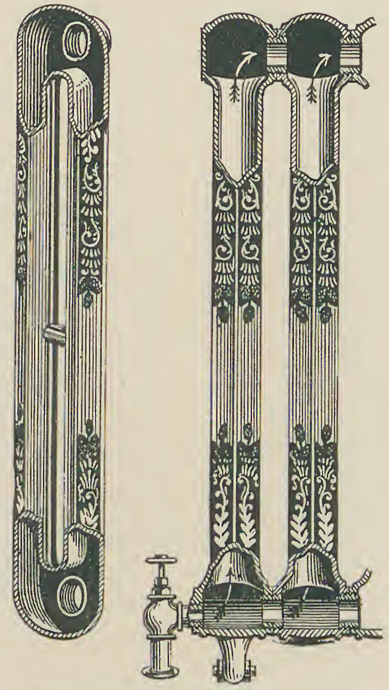


Fig. 528.—Section and View of parts of the "Safford" Radiator for Hot Water.

There are some radiators which are **held together by long bolts.** In my opinion these are distinctly inferior to the kind just described, as the bolts expand and contract, and allow of leakage.

The Coil Radiator, represented in fig. 529, is made by Messrs. W. G. Cannon & Sons, and has been specially designed to afford a large heating-surface in small compass. There is a main bottom pipe, and connected to this are spiral coils of copper. Each coil is free to expand vertically without reference to any other coil, and although such a radiator is more expensive than the ordinary cast-iron type, it is very efficient in working.

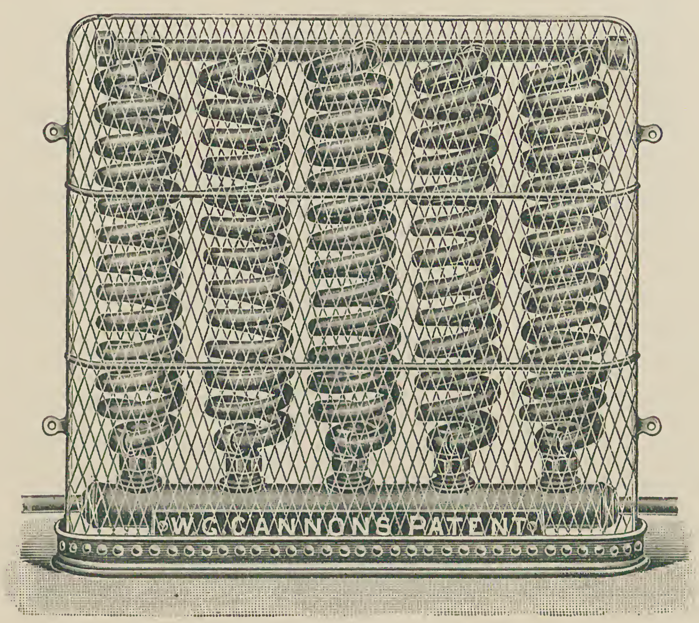


Fig. 529.—Coil Radiator, with Wire Guard.

The coil is shown with a connecting tube at the top, as well as at the bottom,

and the whole is protected by a wire guard, to prevent children from burning their fingers. The same type is also made inclosed in a cast-iron case with a door for access, and hit-and-miss gratings on the top and in front, as shown in fig. 530. There is also a hit-and-miss grating behind, affording access for the external air, which passes out through the upper grating into the room.

I have already drawn attention to the desirability of **warming the incoming air** which is used for heating and ventilation, and the present is a fitting opportunity for pointing out several methods by which this result may be obtained. As shown in fig. 530, a special air-inlet must first be provided in the external wall, and the inside of this opening should be carefully rendered with Keene's or other hard cement. The exterior face of the opening should be protected with a cast-iron grid, which is so fixed in its frame as to be capable of easy removal, when the inside of the opening is to be cleaned. The inner face of the inlet should be provided with a suitable hit-and-miss grating, and the inlet itself should be as near the floor-level as possible; this hit-and-miss grating must be capable of adjustment by means of a handle, which comes to the outside of the case either at the side or at the top. The case itself, which is usually of cast-iron, may be made as ornamental as may be desired, but it should have a hit-and-miss grating of ample size on the top, and also at the front close to the floor. The action of the radiator and case is as follows. In mild weather the inlet-grating is opened to its full extent, the front grating in the case closed, and that in the top of the case opened wide. The heat of the radiator causes an upward current of air through the upper grating, and the external air passes in to take its place. The warmed air passing into the room will have a temperature dependent upon the temperature of the radiator, and upon the velocity of the air passing through the external wall. If now it be found that the volume of air entering the apartment is too large, the grating at the inlet may be entirely closed, and the grating in the front of the case opened. Air from the floor-level of the room will then be drawn into the case, and will pass upwards among the coils of the radiator, and out into the room through the top grating.

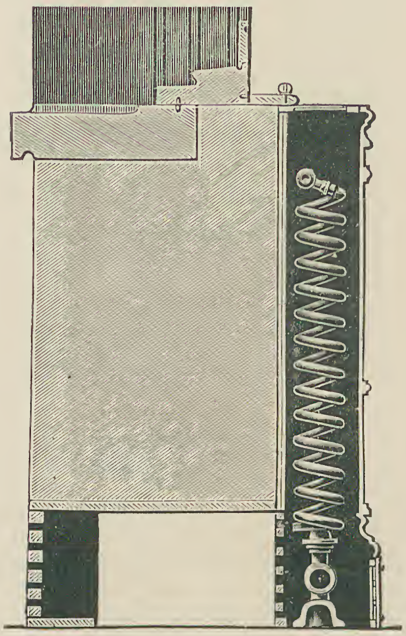


Fig. 530.—Section showing Coil Radiator in Cast-iron Case, with Air-inlet, &c.

There will, in that case, be a circulation of the air in the room only, and the outlet-ventilator, at the ceiling or the floor-level as the case may be, must be kept closed. As no fresh air is allowed to enter from outside, the atmosphere of the room will rapidly become "stuffy", and therefore judgment is needed in opening and closing the external grating.

Such radiator-cases are not considered suitable in all circumstances, but there are other means of arriving at the same end: for instance, fig. 531 represents **a ventilating radiator** quite different from those just described; each separate loop is screwed into the base, and no india-rubber is used in making the joints. In the non-ventilating type the fitting ends with the hollow base into which the pipes are screwed, but in the ventilating type this is fixed upon a special box provided with a large number of small holes in the front of the case near the floor. The usual inlet is provided in the external wall, and protected by a grid. In the base casting a special valve is fixed, consisting of two hinged plates, coupled together by bolts. When this compound valve is pulled forward the holes in the case are closed, and the external air has a free course up between the two rows of tubes, and out through the holes in the top grating; when the valve is pushed in, the external air cannot enter, but the air in the room is free to circulate through the inside of the radiator, as in the case of the radiator previously described. In rare cases cotton cloth or muslin is fitted in the inlet passage, in order to partially clean the air entering the room, but in the great majority of instances this is not done. All arrangements of this kind require attention at regular intervals for cleaning, otherwise they become mere receptacles for dirt, and the air passing into the room may be rendered more impure than the external air.

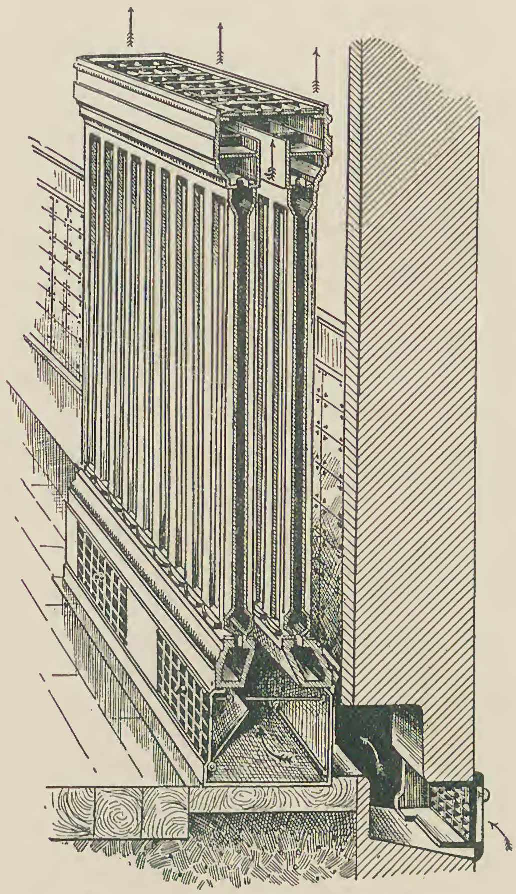


Fig. 531.—Sectional View of Rosser & Russell's Ventilating Radiator.

It is always desirable to have the connections of the pipes to the radiators

made in such a manner as to permit of the **removal of the radiator for cleaning,** as in the last instance it is by no means easy to render the lower box perfectly clean. The dark stain, which will appear above the radiators if they are placed against a wall will clearly prove what a quantity of dust is carried up with the current of heated air.

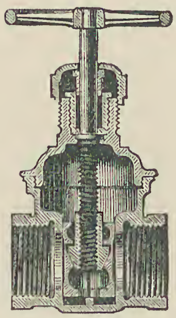


Fig. 532.—Section of Full-way "Peet" Valve.

Stop-valves are very important items in a heating-installation, and it is very poor policy to buy cheap valves, as these are a never-ending source of annoyance. For hot-water work there can be nothing better than a full-way cock, either of the "Peet" type, shown in section in fig. 532, or one of the other types described later. The "Peet" valve consists of two separate disc faces, separated by a wedge-shaped part controlled by a screw. When closed, the two discs shut tightly upon their seatings, and are held there by the pressure of the hand-screw. Such valves are not so suitable for steam, but are well adapted for hot water; the great point which requires attention in a hot-water heating-installation, is that no resistance which can possibly be avoided be offered to the passage of the current.

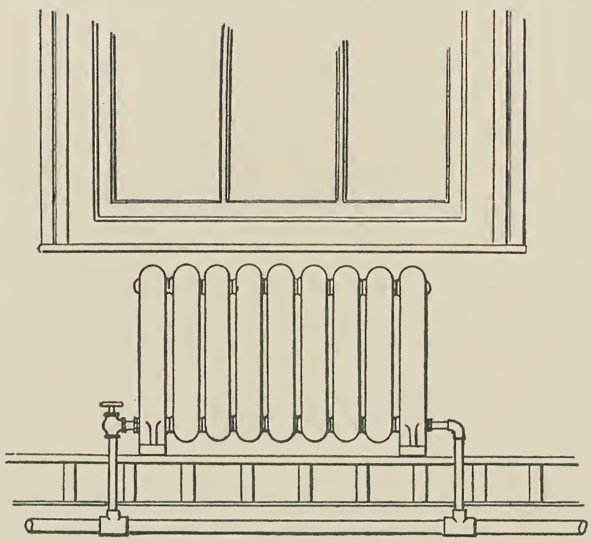


Fig. 533.—Radiator with Elbow Stop-valve.

Another type of stop-valve is shown in fig. 533, and is specially adapted to form an elbow for a radiator connection. These valves should be of gun-metal of good quality, and the plug may consist merely of a conical plug, fitting into a hole turned accurately to receive it; the plug is entirely withdrawn when the valve is fully open, and therefore leaves a full water-way.[1]

Having described in some detail the various pieces of apparatus used in hot-water heating, I shall now consider **the various ways in which the apparatus may be arranged.** The heat, whether obtained from the combustion of coal or coke, gas or oil,

[1] **Safety-valves** are important adjuncts of hot-water apparatus. Numerous explosions, many of which have been attended with loss of life, have occurred in consequence of the omission of these safeguards. The principal cause of explosions is the blocking of the pipes with ice in frosty weather, but stoppage by incrustation may also occur. The simple dead-weight safety-valve is among the best, but as the subject of safety-valves has already been treated in Section IV., pages 275 to 279, nothing further need be said here.—Ed.

must be applied to the lowest part of the system, for the simple reason that heated water will naturally be forced upward by colder water. From the usual tables we learn that, when water is heated from 32° to 212° Fahr., it will expand about one-twentieth of its original volume; such an amount of expansion must obviously be allowed for in any form of apparatus, and if this is not done, the containing parts will be liable to burst. In a low-pressure system the pipes must be open to the air at one or more points. Fig. 534 shows the simplest possible system for heating pipes by low-pressure hot water. T represents an open metal tank filled with water, with a pipe connected to it as shown. So long as the tank and pipe are full of water at the same temperature, there is no tendency to circulate, but let a lighted lamp

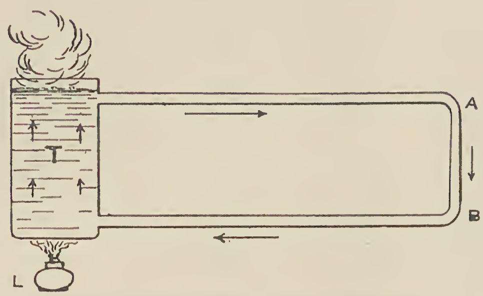


Fig. 534.—Simplest System of Low-pressure Heating.

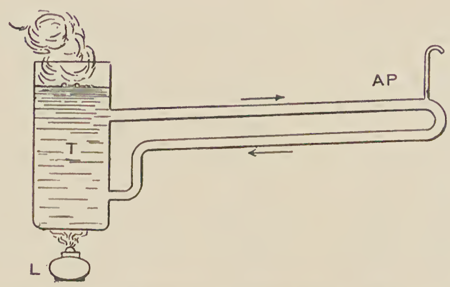


Fig. 535.—Simple Low-pressure Hot-water Apparatus with Air-pipe.

L be applied to the bottom of the tank and heat the water contained therein, then the water in the portion A B will be colder, and therefore heavier, than the corresponding column in the tank, and the action of gravity starts a circulation in the direction shown by the arrows. Now, such an apparatus is obviously too crude to be of practical use. A large amount of heat is lost from the exposed surface of the water, and if the water is lowered by only a slight amount, the upper connection of the pipe will be uncovered and the circulation stopped; but by far the most serious objection is, that it is impossible to carry any part of the pipe above the surface of the water. Air is always present in water, and in such an apparatus bubbles of air might easily collect at A, and impede the circulation. The latter difficulty could be overcome by arranging the pipe as in fig. 535, with a rise to the point A, and there providing an outlet by means of the air-pipe A P.

In the application of the system to practical cases **several points must be carefully observed:**—

(*a*) The heater must be below the lowest part of the circulation-pipes.

(*b*) Means must be provided for the expansion of the water produced by the application of heat.

(*c*) Means must be provided for keeping the apparatus full of water.

(*d*) The circulation-pipes must rise continuously to the highest point and then return gradually to the heater.

(*e*) Means must be provided for ridding the apparatus of air.

Fig. 536 represents diagrammatically **an apparatus for heating two floors** one above the other. The heater is placed in the basement, and of course cannot be left open as those shown in figs. 534 and 535. At a point somewhere above the highest part of the heating-apparatus, will be placed the expansion-tank, which also acts as a feed-cistern for the apparatus; this is marked XT, and is fed with cold water from any convenient source by the pipe CW. The water in this tank never rises more than (say) 4 inches above the bottom of the tank, and actuates a float, which controls the inlet-valve just as an ordinary ball-cock does, but in this case the valve itself is preferably put outside the tank, and the tank covered over and provided with a vapour-pipe VP, which is carried into the open air over the roof. From the top of the heater is carried the rising main, which goes direct to the highest part of the building, and thence round the two floors in the manner indicated. This pipe itself, if of adequate size, would effect the heating of the rooms, but there are several reasons why it is generally inadvisable to use such pipes in houses. In order to obtain the

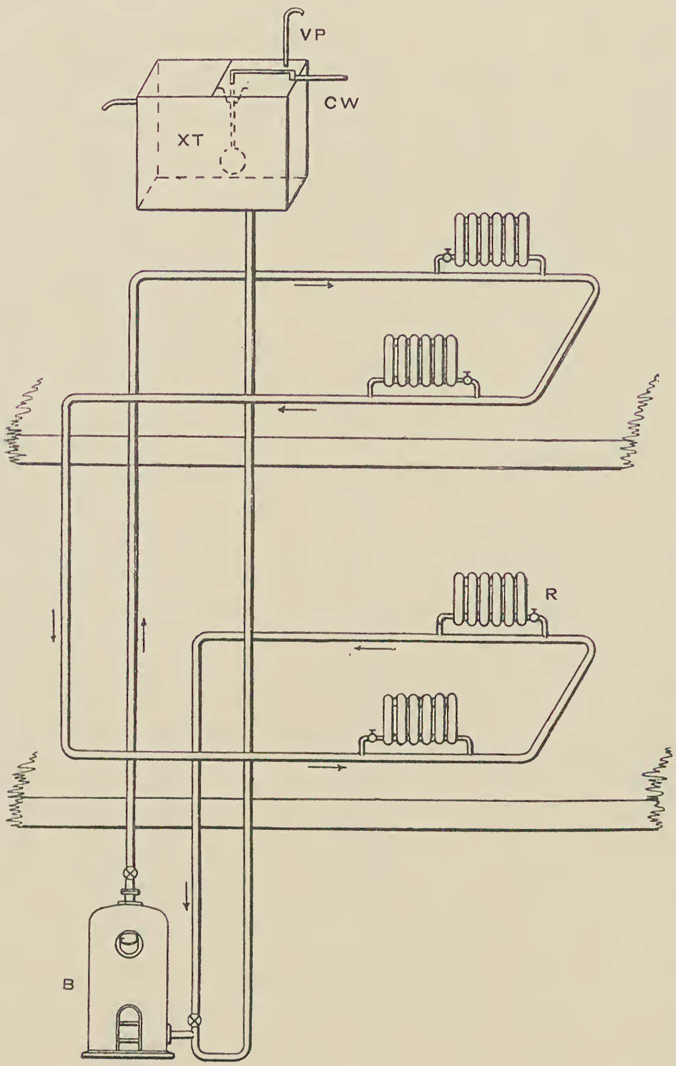


Fig. 536.—Diagrammatic View of Low-pressure Hot-water Apparatus for Heating two Floors with one Circuit.

requisite surface in the length disposable, it would be necessary to use pipe from 3 inches to 4 inches in diameter, and this would seldom be convenient in a private house, as there are doorways to be passed, and a large pipe is very unsightly. A small pipe can be run behind a skirting-board, or under the floor-boards; branches are then taken off to each radiator as shown, and the only parts of the apparatus above the floor are the radiators and their connections. These connections are all taken off the return-pipe, which descends to the heater and is connected to it at or near the bottom; a pipe is carried down from the expansion-tank, and has a U-shaped bend at the bottom, connected to the return-pipe close to the heater. The action of the apparatus will be as follows. With the system full of cold water, the height of the water in the expansion-tank will be (say) 4 inches; as soon as heat is applied, the water will expand up the vertical pipe into the tank XT, and will close the ball-cock, and if it should expand sufficiently, it will pass away by the overflow; hot water will then pass round the system in the direction of the arrows. The valves are marked by an X within a circle. It will be seen that, while the whole of the system can be shut off from the boiler, it is impossible for high pressure to be got up in the boiler, as it is always in open connection with the expansion-tank; the worst that can happen is for boiling water to pass up into the expansion-tank.

This is probably the cheapest scheme which could be devised. The main pipes might be $1\frac{1}{2}$ inches in diameter, and the branches to the separate radiators $\frac{3}{4}$ inch. The heat in each of the radiators can be readily controlled by the valve next to it, but there is no means of emptying a portion of the apparatus so as to allow of the repair of a joint or other similar work. If a second stop-valve were put on the other side of each radiator, this would allow the radiator itself to be removed, but as it would add about 7*s.* 6*d.* to the cost for each extra valve, it is not usually done. Although only two radiators are shown, it is by no means intended that the number should be so limited.

The methods of connecting radiators with the system of pipes deserve mention. It will be observed that, in the last figure, each radiator has a branch off the main, and another back into it, as shown more clearly in fig. 537. In fig. 538, an alternative arrangement is shown with the inlet branch off the flow-pipe and the outlet into the return. If the radiators were arranged so closely together as shown, they might work quite well under the alternative arrangement, but there is always the danger of a short circuit being set up from flow to return, so that while the first radiator would get thoroughly hot, the second might be only warm, and the third almost cold. Such a

thing could not occur with the upper arrangement, and it should always be used except where the branch off the main is so long, and feeds so much radiating surface, that the water is at a very low temperature when it gets back.

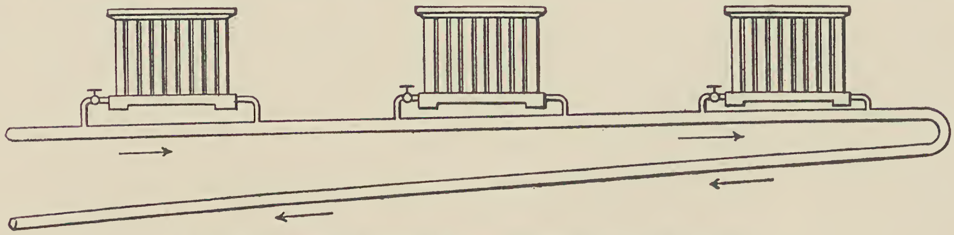


Fig. 537.—Method of connecting Radiators to one Circulation-pipe only.

It is advisable then, and then only, to use the lower arrangement. Radiators connected to a branch circulation-pipe are often on the one-pipe system, as shown in fig. 539. A great saving of pipe can thus be effected, upon what

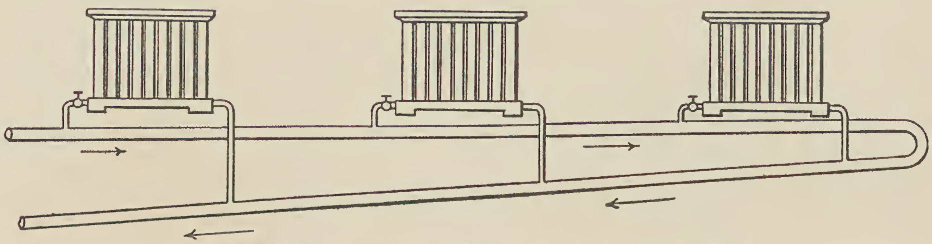


Fig. 538.—Method of connecting Radiators to Flow and Return Pipes.

would be required if both the flow and return pipes were carried along side by side, and the connections made as in fig. 538.

Another arrangement of pipes is illustrated in fig. 540, where each floor is shown to be warmed by a separate circuit. This arrangement is usually adopted in large buildings. Each floor can then readily be shut off, and means can be provided for emptying each of the mains separately at the points c c. It will be necessary to provide air-cocks at the highest point of each of the horizontal runs. It is often somewhat difficult to arrange a method of carrying horizontal pipes on upper floors; doors may be so placed that it is impossible to carry the pipes above the floor, and it may be very difficult to form a suitable channel in the floor itself.

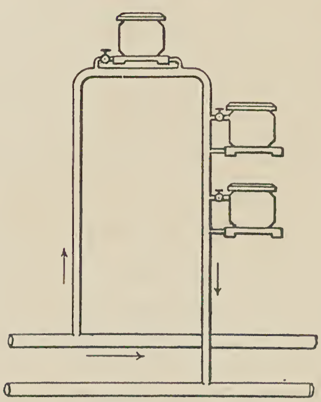


Fig. 539.—Radiators on Branch Circulation-pipe.

For the heating of a ground-floor, **the position of the pipes** may be just below the basement ceiling, as shown in fig. 533. This illustration shows the

main pipe of wrought-iron $1\frac{1}{2}$ inches in diameter, carried in the basement just below the ceiling, and from it are taken off the branch flow and return pipes to the radiator. The radiator should preferably be placed in a window recess, or, if the reveals of the window are not carried down to the floor, it should be placed as close to the wall as possible. An upward current of heated air is then created, which prevents cold draughts from passing direct from the window into the room. Such radiators may be arranged to ventilate the room as well as warm it by direct radiation, if a suitable grating be arranged in the outer wall, and

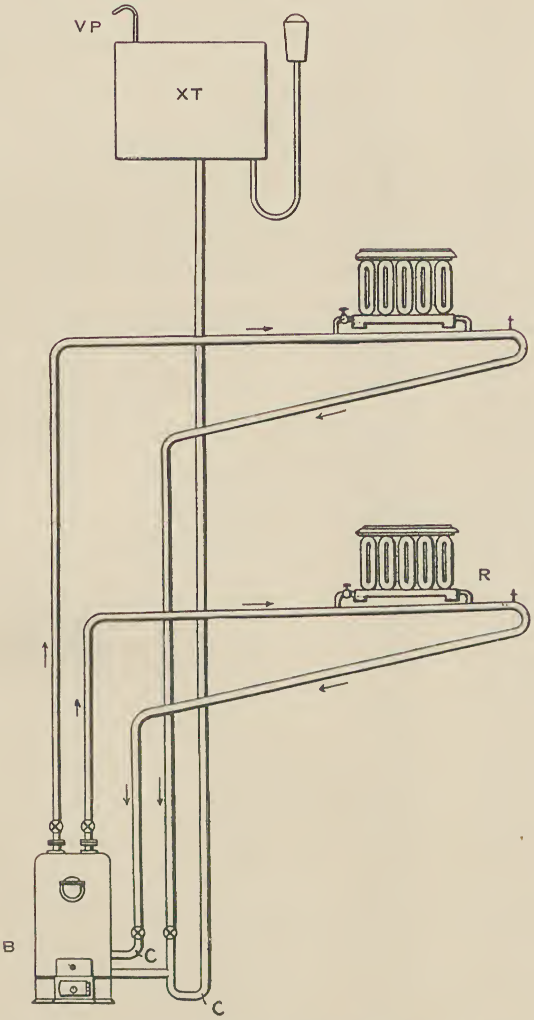


Fig. 540.—Elevation of Low-pressure Hot-water Apparatus, with Separate Circuit for Each Floor.

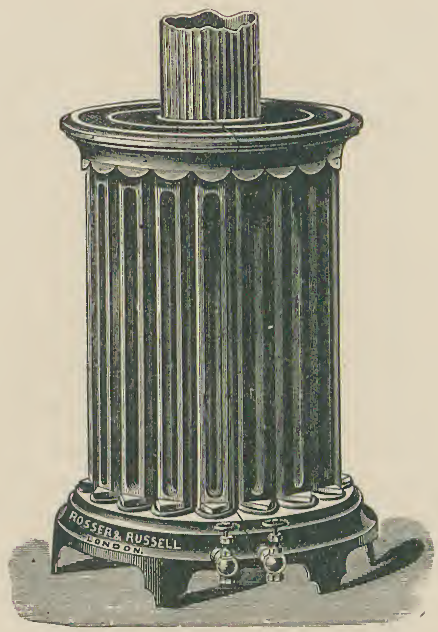


Fig. 541.—View of Circular Radiator for Hall.

suitable baffle-plates inside; details of these have already been given in figs. 530 and 531. For the hall, a radiator of the type illustrated in fig. 541 may be used.

In heating the rooms on the first-floor the same plan cannot be adopted, as of course the main pipe could not be carried through the best rooms on the ground-floor. One plan, therefore, is to prepare a special pipe-channel behind

the skirting-board, as shown in fig. 527, page 124, but even this is not always possible on account of doorways. The pipes, may, however, sometimes be carried between the joists, but should in all such cases be covered to prevent radiation of heat.

Another arrangement of pipes may be adopted, which consists in carrying a main of suitable size entirely around the basement, just below the ceiling, and

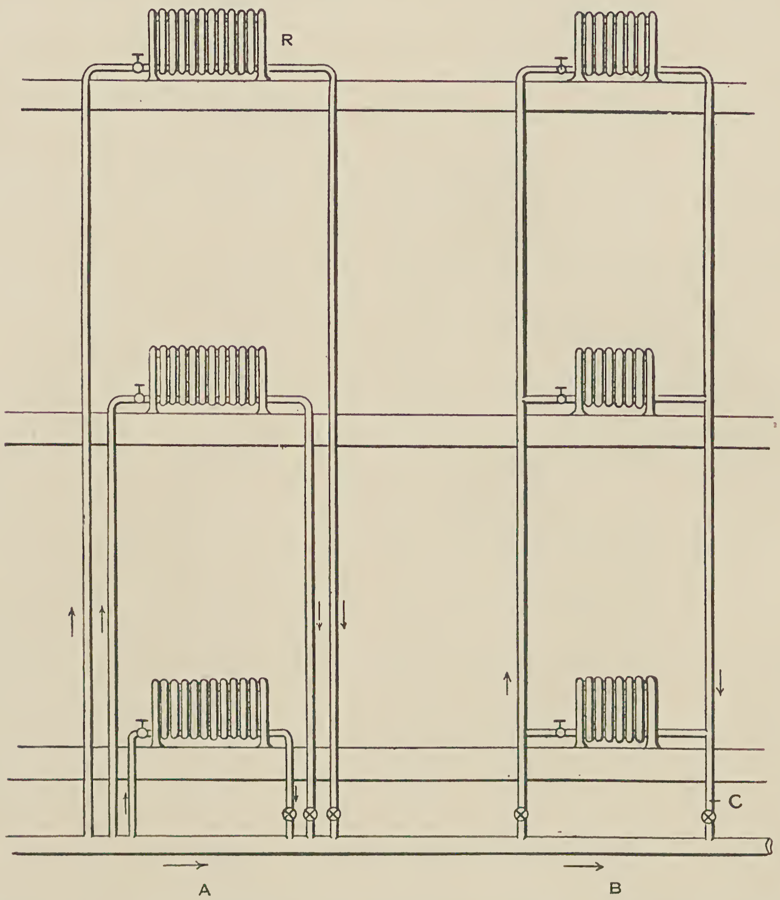


Fig. 542.—Elevation of Pipes for Low-pressure Heating, showing two Arrangements of Vertical Flow and Return Pipes for Radiators.

taking vertical flow and return pipes from this, as shown in fig. 542. In the part lettered A, each radiator has a special flow and return; there is, therefore, nothing whatever to interfere with a good and efficient circulation. The only objection to the system is the number of pipes required. In part B another system is shown, in which there is only one vertical flow and one vertical return; the sizes might be $1\frac{1}{4}$ inches to the first branch, 1 inch thence to the second branch, and $\frac{3}{4}$ inch to the top radiator. It would be well to have a stop-cock close to the main, in both flow and return pipes, and if an outlet be arranged at

c the whole of the loop can be emptied, except the short flow-pipe as far as the first branch. The disadvantage of such an arrangement as that shown, is that the water may flow past the ends of the branches without entering them. There is not the slightest risk about the top radiator, as that is sure to heat well, but there is always a danger that the ground-floor radiator may not get satisfactorily hot. In most of the illustrations, the flow and return pipes are shown to be connected with the same main-pipe, but in some cases, where there is a very long run of branch-pipe before it returns to the main, it is desirable to take the return-pipe back into the return-main, as shown in fig. 539, page 132, as the two last radiators would receive water at too low a temperature to work efficiently, if the long loop were connected up to the flow-pipe only.

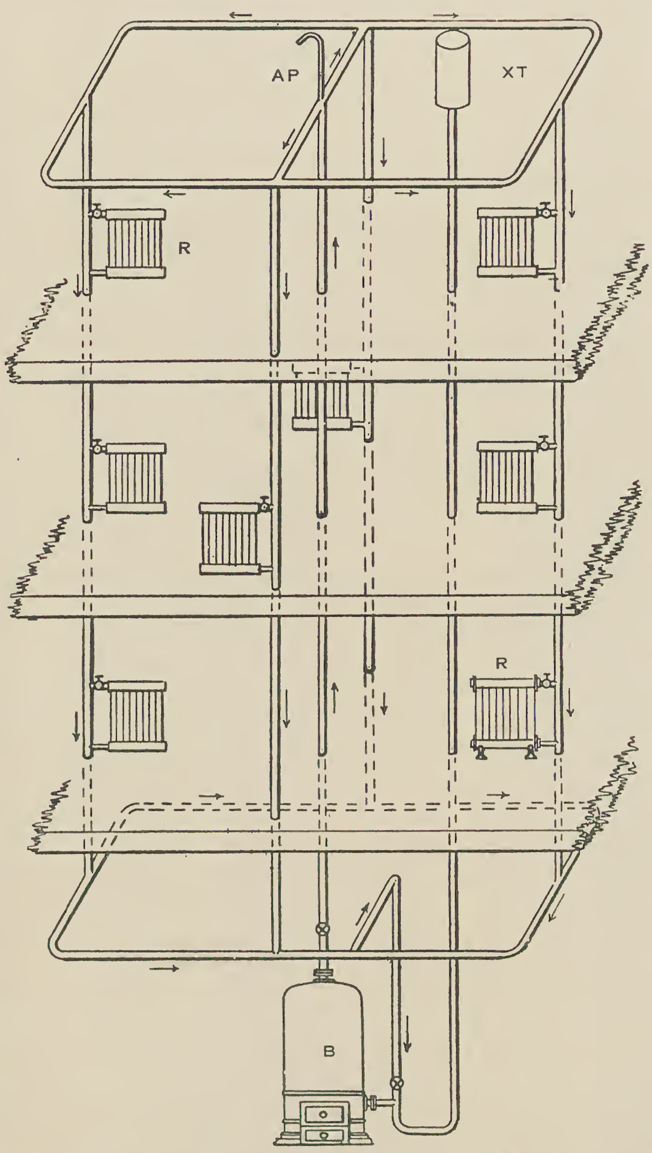


Fig. 543.—Diagrammatic View of the "Mills" System of Piping for Low-pressure Hot-water Apparatus.
B, boiler; R R, radiators; AP, air-pipe; XT, expansion-tank.

Another plan, which has been widely adopted in the United States, and generally referred to as **the "Mills" system of piping,** is to take the flow-pipe direct to the top of the building, and thence to take a number of pipes down as returns to the boiler, as shown in fig. 543. Here the flow-pipe is carried up to the top floor, and feeds a ring-main carried round the building; from this ring descend vertical pipes to a similar ring in the basement, and from the latter ring is taken the return-pipe (or pipes) to the boiler. This gives a very satisfac-

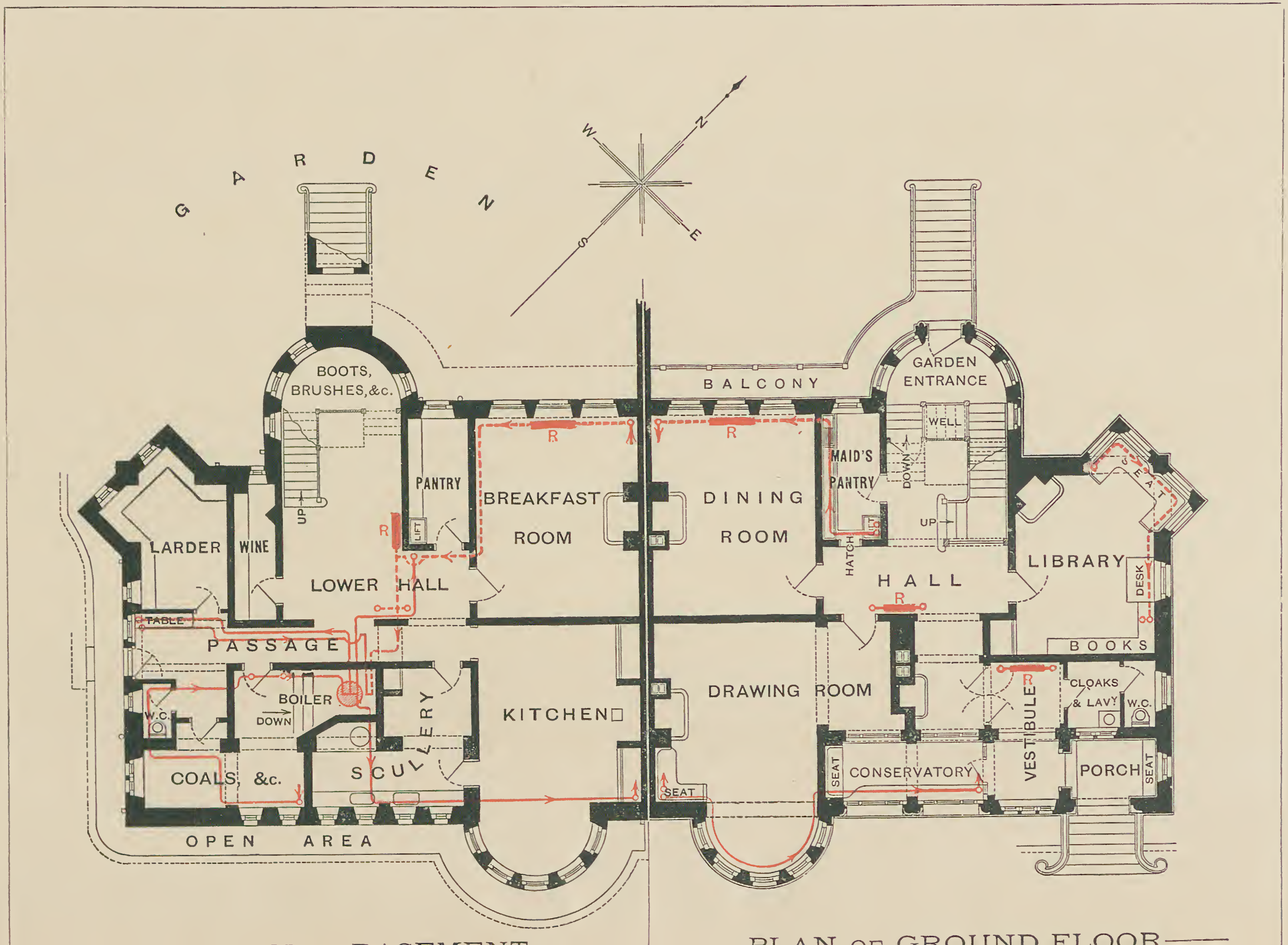
tory result, but if it be considered unwise to depend upon a single flow-pipe, it is easy to take a flow up to the top for each loop. This arrangement is well adapted for use in tall houses of four or five floors; it is, however, open to the objection that the hot water may pass the branches to the radiators without entering them, although it must be said that there is less chance of this in the present case than in that illustrated in fig. 542. When only one flow-pipe is employed, it should have an area approximately equivalent to that of all the return-pipes taken together.

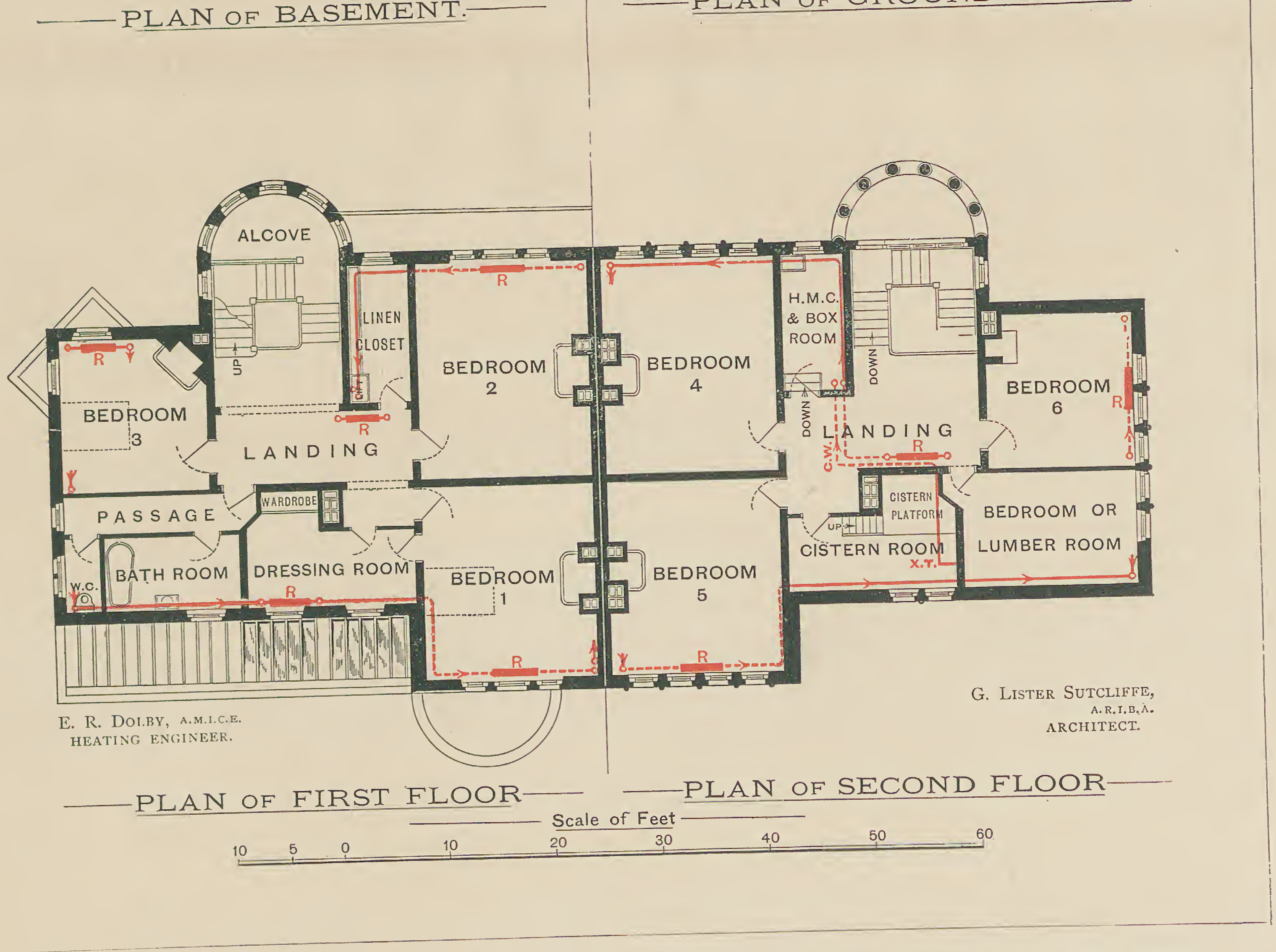
In cases where there are no intervening doorways or fireplaces, **a 3-inch or 4-inch cast-iron pipe** may be arranged, as shown in fig. 520, page 122. This is fed by a small wrought-iron pipe, and for small bedrooms or basement rooms quite sufficient heat will be obtained at much less expense than if radiators are used. In private houses, it is not likely that such an arrangement will be considered suitable, except for servants' rooms.

The low-pressure heating-apparatus for a suburban house is shown in Plates XVIII. and XIX. The vertical type of boiler has been chosen, as it takes up the least room; it is fixed at a level of about 18 inches below the basement floor, in order to allow for the return of certain pipes which are carried below the basement passage. The smoke-flue from the boiler consists of an iron tube carried into any convenient flue which can be used. The boiler itself is provided with a multiple pipe for the flow, and a similar pipe for the return, a "multiple pipe" being merely a pipe provided with several branch-outlets. The expansion-tank marked X T in Plate XIX. is placed in the cistern-room, and fed from the cold-water cistern. A pipe descends direct from this cistern to the boiler to provide a constant feed. There is absolutely no danger of explosion,[1] as the expansion-cistern is open to the atmosphere through a vapour-pipe carried through the roof, as shown in the plate.

Three distinct loops of heating pipes are provided for this house. The flow-pipe of *the first loop* begins at the multiple pipe on the top of the boiler, rises to the ceiling of the boiler-house, passes along close under the ceiling of the scullery and kitchen, and rises in the corner of the kitchen through the ground-floor into the drawing-room; there it rises vertically inside a case, passes through the first floor, and rises vertically through bedroom 1 into bedroom 5; in bedroom 5 it is carried along the floor inside a skirting-case, feeding a radiator at the window, then passes alongside the wall in the cistern-room without any

[1] During the winter of 1896–7, not less than *three* explosions of low-pressure heating boilers occurred, killing one man, injuring another, and doing considerable damage to property, and in every case there was an expansion-cistern open to the atmosphere. The pipes were, however, blocked with ice. The statement in the text is true, so long as the water-way in all the pipes remains open.—ED.


GARDEN
N
S
E
W
BOOTS, BRUSHES, &c.
UP
PANTRY
LIFT
BREAKFAST
ROOM
BALCONY
DINING
ROOM
MAID'S PANTRY
GARDEN ENTRANCE
WELL
DOWN
UP
LIBRARY
SEAT
DESK
LARDER
WINE
LOWER HALL
R
HATCH
HALL
BOOKS
TABLE
PASSAGE
BOILER
DOWN
W.C.
SCULLERY
KITCHEN
DRAWING ROOM
CLOAKS & LAVY
W.C.
VESTIBULE
COALS, &c.
SEAT
CONSERVATORY
PORCH
SEAT
OPEN AREA



PLANS OF A PAIR OF SUBURBAN HOUSES, SHOWING SYSTEM OF HOT-WATER PIPES FOR HEATING PURPOSES.

The pipes in the basement are nearly all carried along the ceilings. The arrows on the pipes indicate the direction of the flow. R R = Radiators.

casing, and is carried similarly through the lumber-room; thence it descends into the W.C. on the first floor, passes along just above the floor of the bath-room, feeds a radiator in the dressing-room, and is then carried in a skirting-case through bedroom 1, feeding a radiator at the window, descends in a case in the corner of the drawing-room alongside the flow-pipe, and feeds a coil inside a casing carried round the bay-window of the drawing-room, this case being fitted with an open-work front; the pipe then passes along the conservatory, feeding a coil placed below the flower-stands, descends through the ground-floor into the coal-cellar, feeding a radiator in the porch, and passes close to the ceiling through the W.C. into the boiler-house, feeding a radiator in the vestibule, and then passing down is connected to the main return.

The second loop runs as follows:—The flow-pipe begins at the multiple pipe on the top of the boiler, rises to the ceiling, passes across the passage close under the ceiling, across the lower hall, rises through the ground-floor, passes vertically upwards inside the lift in the maid's pantry, and thence into the box-room on the second floor. The radiator on the landing of the second floor is fed from it, and it is then carried along the floor through the box-room, through bedroom 4, descends to bedroom 2, passes along bedroom 2 in a skirting-casing, feeding a radiator at the window, and thence along the floor of the linen-closet, feeding a radiator on the landing; it descends inside the lift to the maid's pantry on the ground-floor, and passes into the dining-room, running in a skirting-case and feeding a radiator at the window; it then descends into the breakfast-room, and is carried round two sides in a skirting-case, feeding a radiator at the window; it is afterwards led across the lower hall and passage in a small channel provided with a cover, and feeds a radiator in the lower hall and also one in the hall on the ground-floor.

The third loop runs as follows:—It rises to the ceiling of the boiler-house, then running below the ceiling of the passage rises into the library, passing up inside a special casing into bedroom 3, thence into bedroom 6, and passes along the side of this bedroom in a skirting-case, feeding a radiator at the window; it descends in the corner into bedroom 3, feeds a radiator at the window, and descends again into the library, there passes round the window, feeding a coil, and runs in a skirting-case along the wall, and finally descends into the basement and back to the boiler beside the flow-pipe.[1]

[1] Every hot-water warming-apparatus must have a draw-off cock fitted to the boiler, or to the return-pipe near it, in such a manner that *all* the water throughout the system can be drawn off. The emptying of the pipes, &c., is a necessary preliminary before certain repairs and alterations can be executed, and during winter ought to be effected *whenever the fire under the boiler is allowed to go out.* Allowing the fire to go out and the pipes to remain full of water is the most prolific cause of boiler-explosions.—Ed.

2. *THE HIGH-PRESSURE SYSTEM.*

In my description of the low-pressure system of heating by hot water, it was pointed out that the apparatus was in communication with the open air, so that no pressure, except that due to the height of the water in the apparatus, was possible. If, however, the apparatus be made of sufficient strength, it may be closed entirely, and in that case temperatures may be attained which cannot be reached with the low-pressure system. It is quite usual for a high-pressure system to show **a temperature of 300° to 350° Fahr.** on the pipe-coils, whereas with low-pressure coils a temperature of about 150°–180° is usually not exceeded.

Mr. A. M. Perkins was the inventor of **the high-pressure system** about the year 1837, so that it is by no means a novelty to-day. The system consists in the use of very strong wrought-iron pipes, having an internal diameter of about $\frac{7}{8}$ inch, and an external diameter of $1\frac{5}{16}$ inch. These pipes are joined together in the manner shown in fig. 544; the end of one pipe is tapered both inside and outside to a sharp edge, and the end of the other is left square, and one

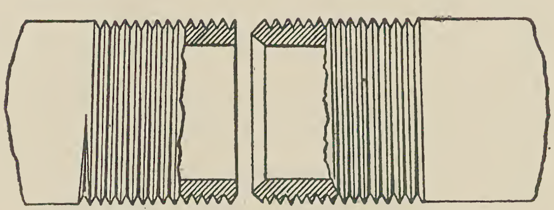


Fig. 544.—Method of Joining Pipes for High-pressure Heating.

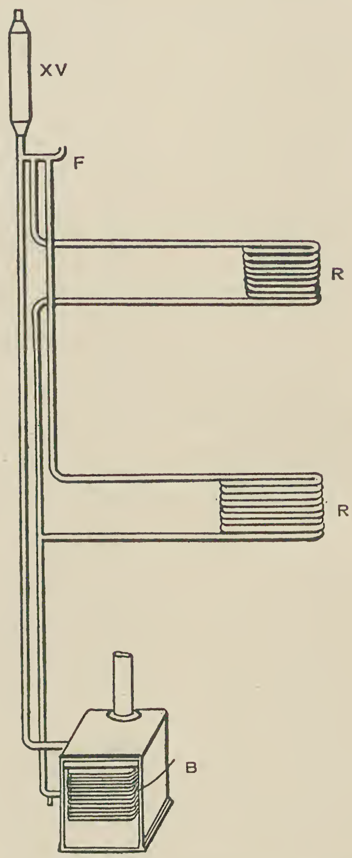
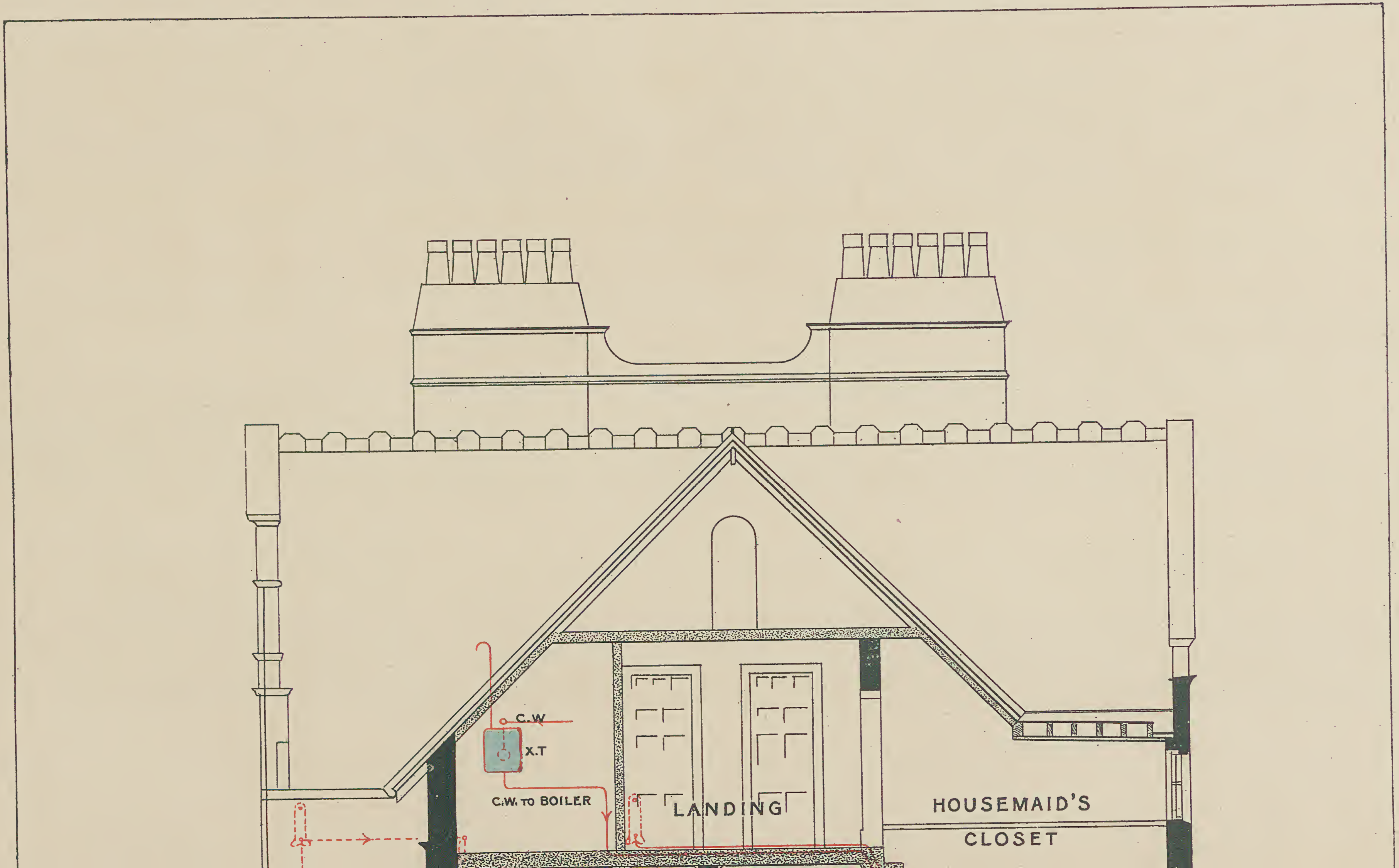
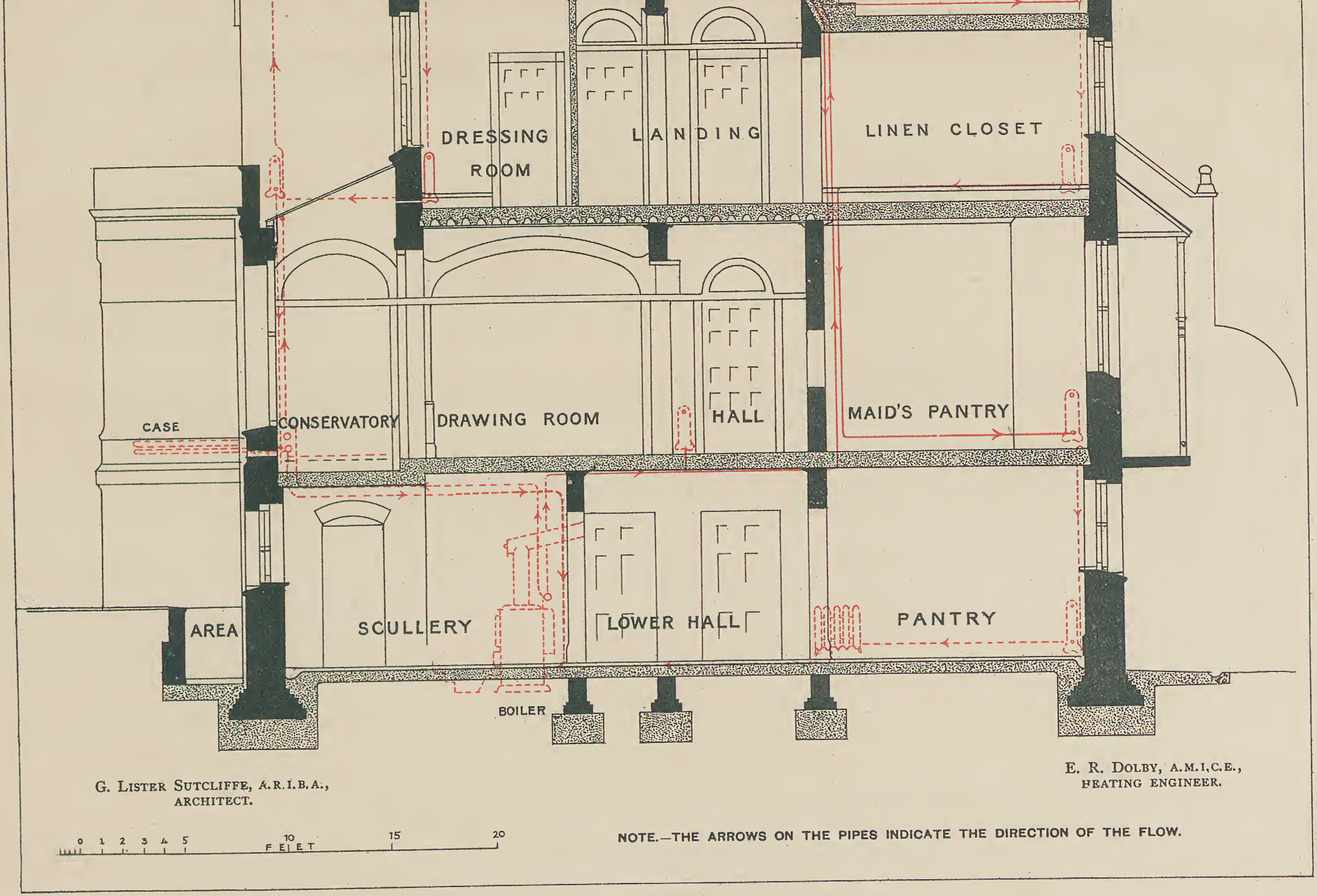


Fig. 545.—View of High-pressure Hot-water Apparatus. B, boiler; F, filling-pipe; XV, expansion-vessel; R R, radiators.

end is threaded with a right-hand thread and the other with a left-hand thread. The two pipes are connected with a right-and-left-threaded socket, no jointing material of any kind being used; the sharp edge of the one pipe is merely forced against the flat face of the other. The pipe is continuous throughout, and is coiled upon itself to give the proper heating-surface in the furnace.

The general arrangement of the system is shown in fig. 545. The coil B is placed inside the furnace, and the coils R R are the radiating media; these are


C.W
X.T
C.W. TO BOILER
LANDING
HOUSEMAID'S
CLOSET



SECTION THROUGH SUBURBAN HOUSE, SHOWING HEATING PIPES.

somewhat unsightly, and must be inclosed in ornamental cases if used inside rooms. At the top of the house is fixed a filling-pipe F, which can be sealed off with a proper plug, and above that is an air or expansion-vessel X V, consisting usually of a piece of pipe of rather larger diameter. No air-cocks are required, and no cistern for filling the apparatus. It is merely filled in the first place through the filling-pipe F; the stopper is then fixed, and the apparatus may be started. As soon as the fire in the furnace is lighted, the water begins to expand, and compresses the air contained in the expansion-vessel. A very rapid circulation is set up throughout the apparatus, which will of course continue so long as the fire in the furnace is attended to. The smallness of the pipes renders it possible to put them in places where the large cast-iron pipes of the low-pressure system could not possibly be fixed, and floor-channels of very small size will accommodate quite a large number of pipes. The rapidity of the circulation has also another advantage: it enables the pipes to be carried below the doorways, that is, to dip down in a way quite impossible with the low-pressure system. With the latter, the great objection to a "dip" is that the air will become locked in the higher part of the pipe, but this cannot occur with the high-pressure system, as it is pumped quite full of water and then sealed up; for the same reason no dirt can get in, and no extra water needs to be added to make up for evaporation, as no evaporation can occur. The pipes are often run along the whole length or width of a room at the back of the skirting-board, which is then replaced by a metal grating, allowing the exit of the heated air; or a coil is placed inside a special case with hit-and-miss gratings, and an opening to the external air, as already explained in connection with low-pressure radiators. There is some little difficulty about shutting off a portion of the system, and judgment needs to be exercised.

The pipes, being of such small diameter, are of very small capacity, and the volume of water can, therefore, be readily heated to **a high temperature in a very short time;** this is in many cases a distinct advantage, but in a house it is not of much consequence, as the fire in a domestic apparatus is rarely allowed to go out during the whole of the cold season.

The small volume of water in the pipes renders the system particularly liable to **fluctuations of temperature,** due to the varying condition of the fire in the stove, and this needs somewhat more careful attention than that of an ordinary low-pressure apparatus. Again, if stop-valves are used to shut off part of the apparatus the fire must be regulated to suit, otherwise the proportion of pipe in the stove will become excessive for the length used as a radiating medium, and the exposed pipe will therefore become too hot. The usual proportion of

pipe in the stove to the exposed part, is about as 1 to 10 for ordinary heating work. Of course, in the case of a public hall, where all or none of the heating would be required, the problem is simple, but where, as in the case of a house, the requirements fluctuate, the problem becomes somewhat more complicated. Many private houses, however, are satisfactorily heated by this system.

CHAPTER VI.

LOW-PRESSURE STEAM HEATING.

The system of heating by low-pressure steam is very similar to that of heating by low-pressure hot water, except that, instead of having an apparatus quite full of water and open to the air, so that it is not possible to produce steam above atmospheric pressure, the apparatus is closed and never allowed to get full of water. Steam is generated in a special boiler,—which is placed below the lowest point to be heated,—and then passed into a system of pipes, which are carried into the parts of the building to be warmed, and either themselves give off the heat, or feed apparatus specially designed for that purpose. It is obvious that in the passage of steam through a system of cold pipes a great deal of condensation must take place; the water thus condensed must be carried off as fast as it is formed, and should be used over again in the boiler. For this purpose special pieces of apparatus known as steam-traps are used, which allow free passage to the hot water, but prevent the exit of the steam. All the water passing out has at one time been steam, and is therefore perfectly pure, and if used in the boiler will cause no incrustation; besides this, it holds a large portion of the heat which has originally been in the steam itself.

It may now be advisable to recall to mind **a few facts relating to steam,** including its formation, and the heat which is contained in a given quantity. The British "thermal unit" is defined to be that quantity of heat which will raise one pound of distilled water 1° Fahrenheit in temperature; thus the work of raising one pound of water at 32° F. to 212° F. would be 180 thermal units. But to change one pound of water at 212° F. to one pound of saturated steam at 212° F. and atmospheric pressure, will require 966 thermal units, and the heat required to raise one pound of this steam to a pressure of one pound above the atmosphere will be 0·3 thermal units. The large quantity of heat which is absorbed in the change from the liquid to the gaseous state, is called "latent

heat"; this heat is given back during the change from vapour to the fluid state. When steam, therefore, is used for heating purposes, the heat due to its temperature is made use of, and when it condenses in the pipes it gives off the latent heat, and is taken back into the boiler as hot water.

There is a very considerable **difference between steam and hot-water heating** in the following respect: the quantity of heat contained in the pipes of a hot-water apparatus when full of water is vastly greater than that contained in a steam apparatus when full of steam, although the perceptible temperature of the latter, when tested by a thermometer, may be considerably higher than that of the former. It must be remembered that the capacity of the water for heat is much greater than that of the gaseous steam; the result therefore is that, if steam be shut off, it takes but a short time for the pipes to become quite cold, while, in the case of hot water, the heat is retained for a very considerable time. Heating by hot-water pipes is not subject to such rapid fluctuations as may be the case with steam-pipes. In hot-water systems the pipes must have a good fall back to the boiler, otherwise the circulation will be impeded; the air also must be got out of the pipes. In the case of steam systems it is even more important that the condensation or return pipe should fall towards the boiler, otherwise pockets of water will be formed, which will be blown out suddenly by the steam with loud crackling noises. Air must of course also be got out of the pipes, but in the case of steam at low-pressure the air would be heavier than the steam, and would therefore need to be drawn off at the bottom of the apparatus, and not at the top, as would be the case with a hot-water apparatus.

The principal points which require attention in **the design of a low-pressure steam heating-apparatus** are—firstly, that the whole of the parts are amply strong enough to bear the pressure to which they will be subjected, and secondly, that the pipes are so laid that the water produced by condensation passes away freely under the influence of gravitation.

The boilers used for low-pressure steam-work closely resemble those used for low-pressure hot-water heating, and the latter types of boiler are usually made of sufficient strength to enable them to be used for low-pressure steam-heating. Ordinary cast-iron radiators are often used with steam of 25 or 30 lbs. pressure per square inch, and sometimes, indeed, with steam direct from high-pressure boilers working at 50 lbs. pressure; but I strongly object to putting them to such severe tests, and certainly do not consider that more than 5 lbs., or in exceptional cases 10 lbs. pressure per square inch, should be used in private houses. Throughout the following description, it may be taken that steam of about 5 lbs. pressure is alluded to. Boilers for steam-heating should never be built of cast-

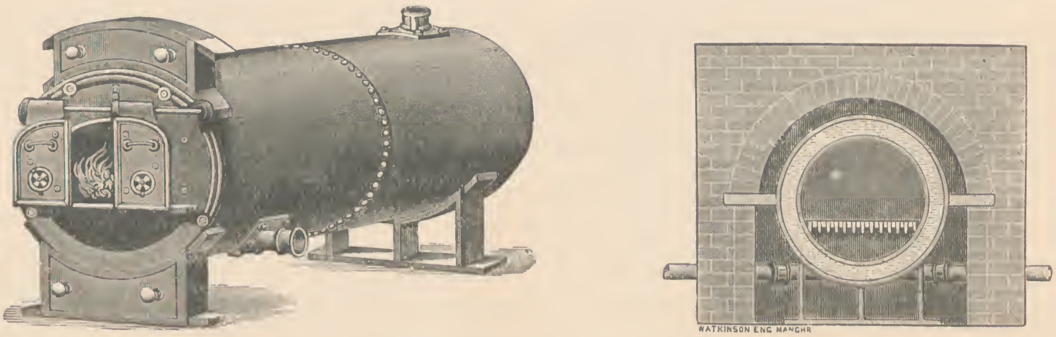
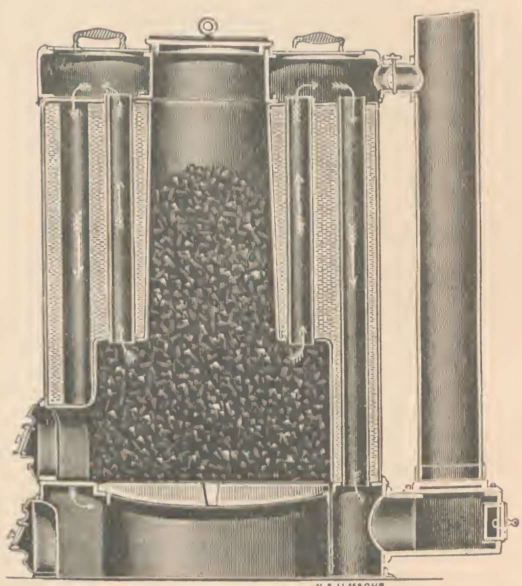


Fig. 546.—View and Cross Section of the "Trentham" Cornish Boiler.

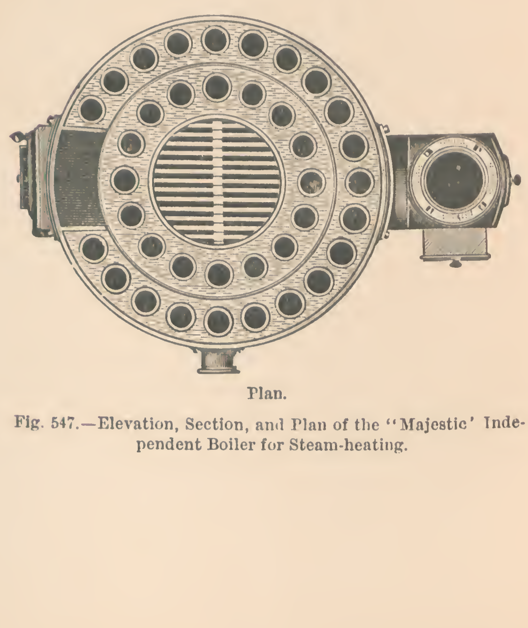
iron. They should have ample steam and water spaces. I consider that no type

Section.



Elevation.

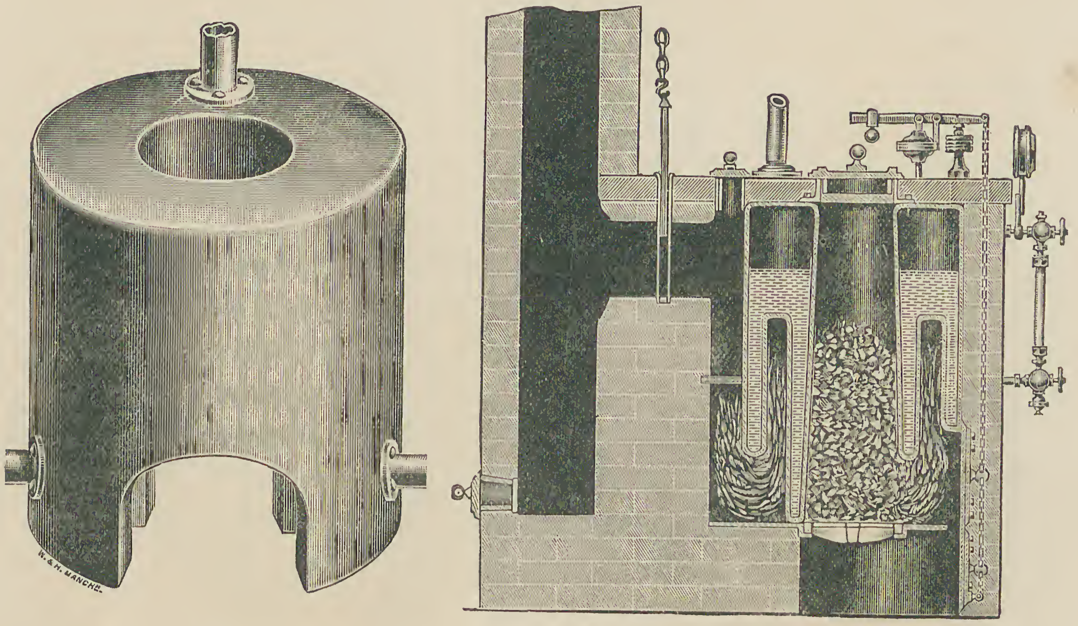
of boiler is so suitable for this work as the ordinary Cornish boiler, that is, a boiler with cylindrical shell and one cylindrical flue, with or without cross tubes, and set in fire-brick with proper side flues. Such a boiler is shown in fig. 546. The grate is inside the furnace-flue, and the products of combustion go from the flue down underneath the boiler, so that the



Plan.

Fig. 547.—Elevation, Section, and Plan of the "Majestic" Independent Boiler for Steam-heating.

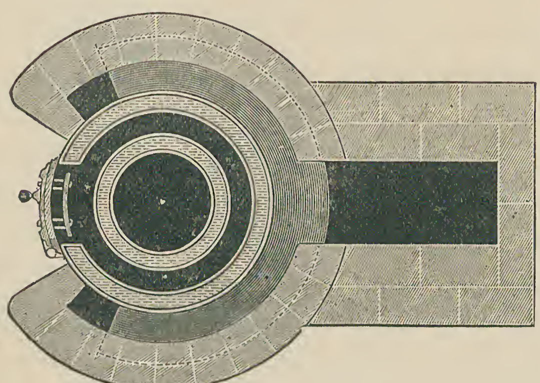
bottom of the boiler receives the hottest gases, and then the draught is split, and the gases pass along the sides and go out into the chimney-stack. Some people, however, prefer to use the saddle type of boiler, with a much deeper crown than in the case of the hot-water boiler, or a waggon boiler, but both these



View. Section.

types are, in my opinion, inferior to the plain Cornish boiler.

In some cases it is very desirable that brickwork should be avoided; **a vertical type of boiler** should then be used, such, for instance, as that shown in fig. 547. This type has the very important advantage that it possesses a central fuel-hopper, so that a considerable charge of coal can be put on at once, and the boiler will not require so much attention. It is arranged with a ring of vertical flue-tubes, through which the products of combustion rise, and also with a second ring of tubes, through which they descend; these tubes are surrounded by the water, so that an



Plan.

Fig. 548.—View, Section, and Plan of the "Caloric" Boiler for Steam-heating.

efficient heating-surface is obtained. A good steam-space is also provided, which is important, as it is very desirable that dry steam should be obtained.

A neat little boiler, which, however, requires brick-setting, is shown in fig. 548. This has also a central hopper for receiving the fuel, and therefore will require less attention than if the door on a level with the grate were the sole means of stoking. The products of combustion pass up into the water-space in an

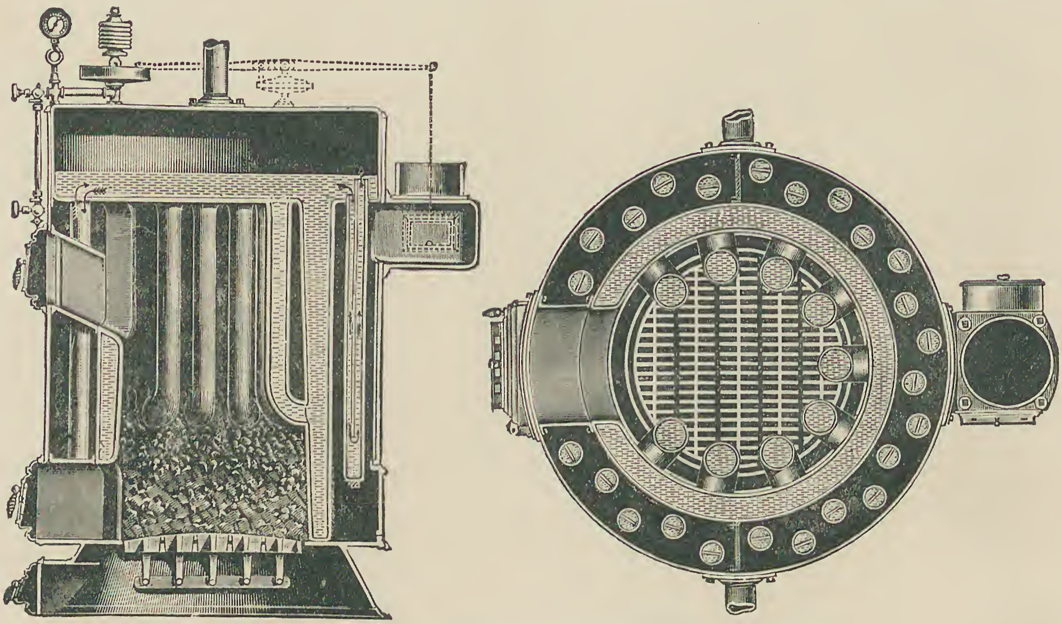


Fig. 549.—Section and Plan of Lumby, Son, and Wood's Patent "Pioneer" Boiler.

annulus before going out to the chimney-stack. One outlet-pipe is provided, and one inlet, although two inlets are shown in the illustrations.

A boiler of somewhat novel construction is shown in figs. 549 and 550, and is known as **the "Pioneer" independent boiler.** As will be gathered from the illustrations, it consists of outer and inner cases, and of a series of water-tubes. It is made in sizes varying in height from 54 to 82 inches; the smallest size is said to be capable of heating 600 square feet of actual radiating surface, and the largest 1750 square feet. These boilers are made of Siemens mild steel plates welded together, and are fitted with safety-valve, water-gauge, and pressure-gauge. It may be remarked in passing that a very similar boiler is made for low-pressure hot-water heating, but in this case the water of course fills the boiler completely.

Every boiler, no matter how small, should be provided with **the following fittings:**—Two safety-valves (one of the lever type, loaded so as to blow off at, say, 5 lbs., and the other a dead-weight safety-valve which cannot be tampered

with, and loaded to, say, 7 lbs. pressure), a reliable pressure-gauge of the Bourdon type, made by some well-known maker, and a water-gauge, so that the level of the water in the boiler may be easily observed. There should be a mark upon the gauge, or a brass pointer should be fixed upon the boiler-casing, showing the proper working-level of the water, so that the attendant may observe instantly if the water is getting too low. If this were to occur the crown of the firebox would become dry, and might become red hot. Fusible plugs are often inserted to guard against such an occurrence, as the fusible metal contained in them melts out, and the water pours in upon the fire and extinguishes it.

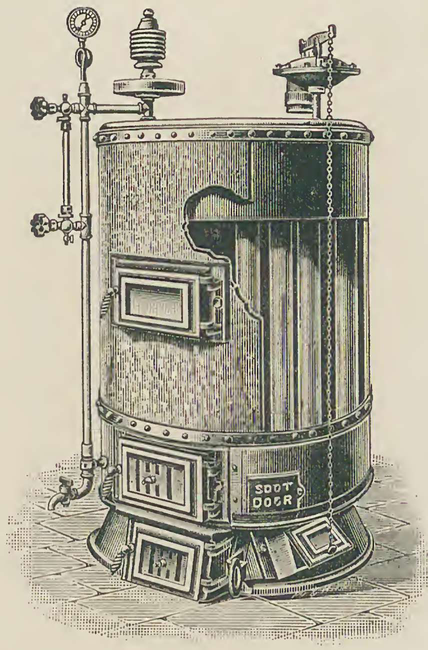


Fig. 550.—View of Lumby, Son, and Wood's Patent "Pioneer" Boiler.

Messrs. Körting Bros. have **a special system of low-pressure steam-heating,** which certainly deserves notice. The boiler itself is represented in figs. 517 and 518, pages 120 and 121. This system differs considerably in many points from the usual methods of heating by steam. Fig. 551 is an illustration of the general arrangement. G is the low-pressure steam-boiler, T the fuel-hopper and patent furnace, *s* the safety-pipe, V V the steam-distribution pipes, S S the coils or radiators to the rooms, *v v* the steam-admission valves, $c\ c'\ c''$ the return-pipes for condensed water, A the air-pipe, W the syphon-pipe between the air and water vessels, R the syphon water-vessel with air-pipe, and R′ the syphon air-vessel. The steam-generator, or boiler, which has already been described in detail upon page 121, is placed in the basement of the building, in as central a position as can be conveniently arranged. The steam generated, at a pressure of $1\frac{1}{2}$ to 5 lbs. per square inch, is conveyed by the steam-distribution pipes V V to the radiators S S. The radiators, which are filled with air from which most of the oxygen has been absorbed, are placed upon the various floors, so that they stand as far as possible in series one above the other, and, where this can be arranged, they have joint condensed-water return-pipes *c c*, falling vertically to the basement, where they are collected into a common main return-pipe at the floor-level. A further connection is made from each radiator to the air-collecting pipe A, which is carried under the ceiling of the basement, and connected to the air-vessel R′, and also by means of a "drain-pipe" C, to the main return-pipe

on the floor. The air-vessel R′ is joined by the syphon-pipe W to the water-vessel R, and as this latter has a pipe open to the atmosphere, it is in consequence always under atmospheric pressure. The capacity of each of the two

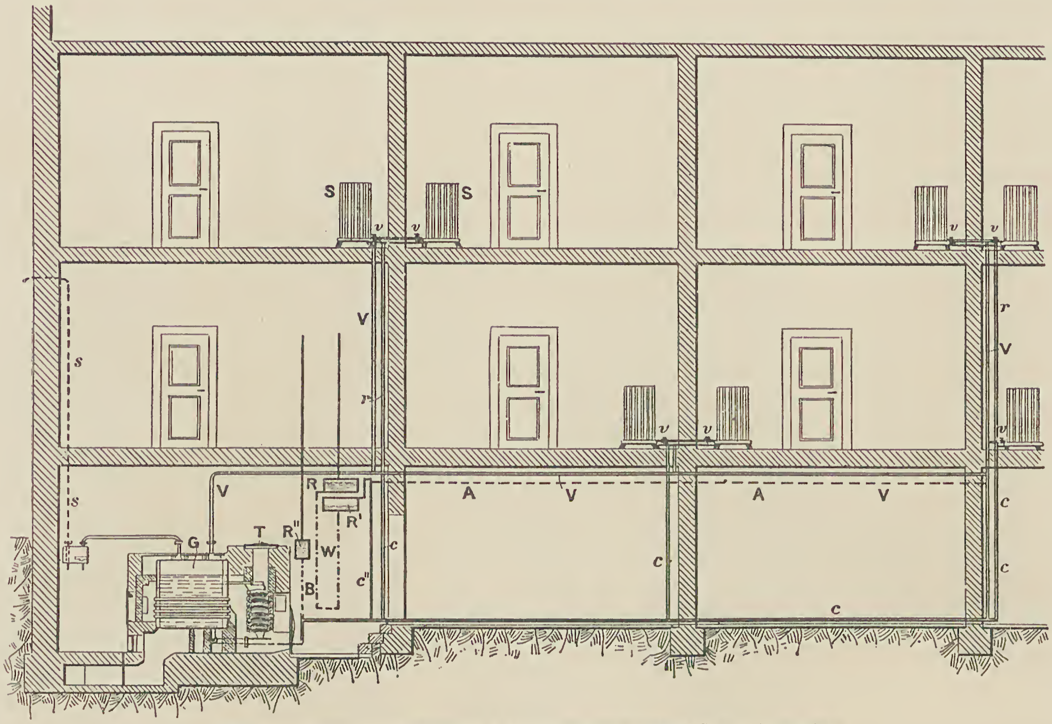


Fig. 551.—General Arrangements of Körting's Low-pressure Steam Apparatus.

A, air-pipe; *c c′ c″*, return-pipes for condensed water; G, low-pressure steam-boiler; R, syphon water-vessel with air-pipe; R′, syphon air-vessel; *s*, safety-pipe; S, coils or radiators in the rooms; T, fuel-hopper and patent furnace; *v*, steam-admission valves; V, steam-distribution pipes; W, syphon-pipe between air and water vessels.

vessels, R and R′, is equal to the total cubic contents of the radiators, the steam connections, and the steam-space of the boiler.

The working of the apparatus is quite simple. The boiler G, and the syphon air-vessel R′, are filled with water to the required level, and as soon as steam is generated in the boiler, the air, occupying the steam-space of the boiler and distribution-pipes V V, is displaced by the steam and driven through the radiators into the vessel R′, displacing in turn the corresponding volume of water from this vessel, and driving it into the vessel R through the syphon-pipe W. Each radiator has a specially-constructed steam-valve, as shown in fig. 552. The valve has an indicator, and by reference to this the degree to which the valve is opened may be ascertained, and accordingly as the valve is more or less opened, more or less air will be forced out of the radiator into the vessel R′. If the regulating-valve be quite closed, the steam in the radiator will quickly condense, and the radiator will again fill with air from the vessel R′.

The advantages of this system are considerable. The air in the heating-system cannot escape, as it is trapped on the one side by the water in the boiler, and on the other by the water in the vessel R, and therefore no fresh air from outside is taken into the system. This fact is of the greatest importance, as the air, hermetically inclosed in the system, loses its oxygen in a very short time, and ceases to have the slightest corrosive action upon the inside of the pipes and radiators. Air-valves are not required, and the regulation of each radiator can be effected perfectly and easily by one steam-valve. The heating may be carried on either continuously or with breaks, as may best suit the character of the building, the season of the year, or the preference of the owner. As all the connections which contain water when the heating is out of use are without exception in the basement of the building, the risk of freezing is very slight indeed, and damage to the radiators and pipe-connections above the basement from this cause is quite impossible. The water-level in the boiler is not subject to any variation during working, as all the condensed water is returned direct by gravitation, and perfect noiselessness of working is secured, if the steam and water never come into direct contact with one another in the pipes.

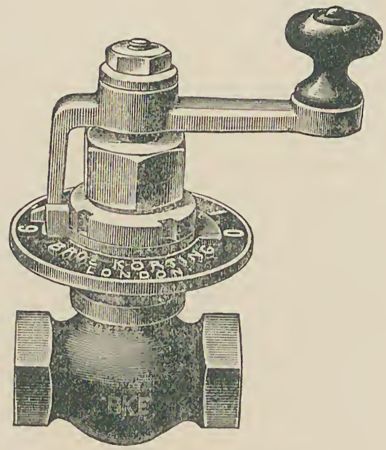


Fig. 552.—View of Steam-valve.

The maintenance of a constant pressure is of special importance in low-pressure steam-heating, and the inventors of this system have designed **an automatic draught-regulator** (shown in fig. 520, page 122), by which this is secured. Q Q_1 are vessels containing mercury, D is the steam connection to the boiler, W the water-connection to the stand-pipe, S a float, H the lever arm, F a movable weight, and V V_1 valves for regulating the admission of the air. The action of the regulator depends upon the change of level of the surface of the mercury in the vessel Q. The upper part of this vessel is connected by the pipe D to the boiler, and the mercury rises and falls as the variation of the steam-pressure in the boiler causes the movement of the float S, which works the lever H, on the ends of which the double valves V and V_1 are suspended. When the pressure in the boiler rises to a certain height, the valve V_1, which regulates the air-admission to the furnace, commences to close, and the valve V, which allows air to pass by a second canal in the boiler-setting direct into the flue, begins to open. When the maximum pressure desired is reached, the valve V_1 is completely closed and the valve V fully opened, so that the fire is deadened and

does not again burn briskly, until the reduction in steam-pressure has resulted in the sinking of the float S, and the consequent alteration of the position of the valves V and V_1.

An improvement has been made in the regulator by the introduction of the movable weight F. By altering the position of this weight, the valve V and the float can be nearly balanced, and it is possible to obtain a constant pressure of from $4\frac{1}{2}$ lbs. down to 0·15 lbs. per square inch. It is thus possible during the night, or at intervals when the heating is not required, to lower the pressure, thus causing the coils in the various rooms to be partly filled with air, and thereby reducing the fuel-consumption during this time to a minimum. When heating is again required, the weight is moved, and the steam-pressure rises; the air is forced out of the coils, and the rooms are warmed without anyone in the rooms troubling in the least about it. The heating of all the rooms is in this way under full control from the boiler-house.

Although, in ordinary working, **an excessive rise in the steam-pressure** is prevented by the draught-regulator, it is conceivable that, by some accident, such an increase may occur. The steam-pressure would then force the water out of the syphon in the stand-pipe; the steam would escape, and the pressure would altogether disappear. In such a case the pressure on the mercury in the regulator would also cease, and owing to the consequent sinking of the float, the air, which had been kept from the furnace by the closed valve V_1, would be admitted again, and there would be risk of burning out the boiler. The regulator is, however, so designed that all such risk is prevented. There is a second vessel Q_1 containing mercury, connected by a small pipe W to the upper part of the stand-pipe. Should the water blow out of the syphon, part of it flows out of the stand-pipe into Q_1, which is thus under water-pressure equal to the height of the stand-pipe. As this pressure is at least as high as the maximum steam-pressure needed to work the float, this will maintain the float in the position in which air is cut off from the furnace, until the water in the pipe W is allowed to run out through the valve E, fig. 519, page 122.

I have entered at some length into a description of Messrs. Körting Bros'. special system, because I consider that their **method of dealing with the air and condensed water** is extremely ingenious. In examining steam-heating plants, one observes constantly that the air-cocks are placed at the top of the radiator coils, either through carelessness, or because the designers do not realize that air is heavier than steam; the result is that air-cocks are opened, and steam is seen escaping, and they are at once shut upon the assumption that no air is present in the coil. The heating is not found very satisfactory, the reason being that

there is always a stagnant body of air at the lower part of each radiator, and this is very difficult to heat to the temperature of the steam. Quite elaborate arrangements of pumps are also provided in order to get the condensed water back into the boiler, although, as already pointed out in describing this system, the whole of this work can be done by gravitation if the scheme is only properly designed.

Messrs. Körting Bros. also state that, for their low-pressure steam-heating, they use as far as possible **radiators** which, according to their latest invention, are not filled with steam alone, but with a mixture of air and steam. Formerly when the steam was admitted to the top of the radiator, it pushed the air partially or entirely out, but steam being lighter than air, the result was that, when not worked to their full capacity, the top of the radiator was actually heated to the full temperature of the steam, while the bottom being full of air, remained cool. Now the steam is admitted by a special arrangement to the bottom, and the steam and air rise and circulate through the radiator, warming the whole of the surface to a lower or higher temperature according to the temporary requirements. The inventors of the system claim that the radiators, although warmed by steam, give the same agreeable heat as low-pressure warm-water coils, without having the disadvantages of that system, and especially without the disadvantages of freezing in winter. Of course the steam-pipes are relatively smaller than hot-water pipes calculated to do the same work, and therefore cost less.

In the chapter on low-pressure hot-water heating, I have described a number of forms of radiators, most of which are equally suitable for steam; the only point to be borne in mind is the position of the air-cocks. The inlet and outlet pipes for steam will also be smaller, and if stock-pattern radiators are bought, it will be necessary to use a nipple to reduce the size of the opening. Messrs. Körting Bros. make a type of radiator with specially thin gills, which is very cheap, and also gives a very large surface for the radiation of heat. Two varieties are shown in fig. 553, the square and the oval. These are solidly constructed, but are not of sufficiently artistic appearance to be used in living-rooms without some kind of ornamental case, which may be either of cast iron or wrought.

The inventors of the system, which has here been fully described, lay down **the following principal requirements,** which should be fulfilled by a low-pressure steam-heating apparatus, and claim that their apparatus fulfils them:—

(1) There must be complete control of the temperature of the rooms heated.

(2) The coils or radiators ought to be below 212° Fahr., as at higher tem-

peratures the small particles of organic matter, which float in the air in the form of dust, are volatilized when coming into contact with the heating-surface, and disagreeable and unhealthy smells result.

(3) The steam-generator must be constructed so as to secure continuous and

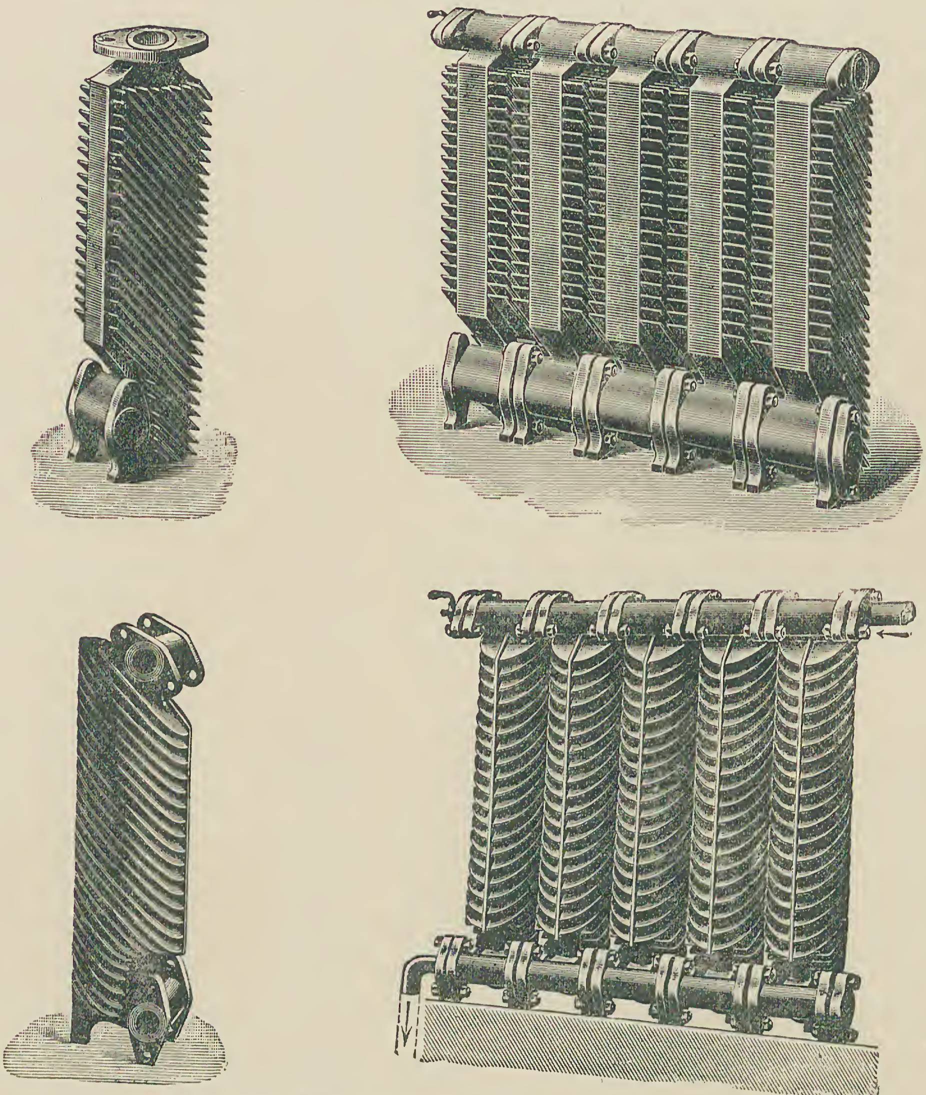


Fig. 553.—Views of Körting's Radiator, Square and Oval Patterns.

efficient combustion of the fuel, to avoid the inconveniencing of the neighbourhood by the emission of smoke, and to prevent any formation of clinker in the furnace. Further, there should be no liability of damage to the generator owing to possible neglect.

(4) The consumption of fuel must be automatically regulated to suit the

variation in the demands on the heating-surface in the rooms, so that the actual weight of fuel burned in the furnace in a given time is proportionate to the amount of heat passing into the rooms from the heating-surface.

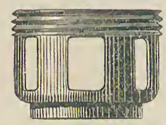
(5) To minimize the attendance, the steam-boiler must have a furnace-hopper of such capacity as to contain fuel sufficient at least for the night, so as to dispense with night attendance, and also to secure that the fuel only needs replenishing at lengthy intervals during the day.

(6) Any portion of the heating-system, which may be liable to exposure to frost, must be quite free from water, when the heating is not in operation.

(7) There must be no liability to rusting, either on the inside or the outside of any part of the heating-system.

Lap-welded wrought-iron pipes, of what is known as "steam quality", should be used, with wrought-iron elbows, tees, bends, &c., throughout. Cast-iron pipes are not suitable for use with steam. The supports for the pipes will be of a smaller and simpler kind than those needed for hot-water work, and generally the whole of the pipes will be of smaller size and will be found much easier to run in confined places; these small pipes can readily be taken behind skirting-boards and in other similar positions, where it might be difficult or impossible to fix hot-water pipes.

Loose valve attached to end of spindle by a nut.



Seating screwed into valve body.

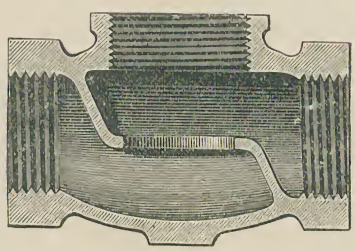


Fig. 554.—Dewrance's Renewable Valve.

The stop-valves used in this work will require to be of a different type. In preference to the "Peet" valve, I use such a valve as that made by Messrs. Dewrance of London with a renewable seating, and illustrated in fig. 554; these cocks have a good seating, and will last a very long time. For the smaller sizes, say up to 2 inches, they are made of solid gun-metal, and in a house it is scarcely likely that valves larger than these will be required. For the condensed-water pipes, a valve such as the Peet valve may certainly be used, as it affords a full way, which is of some advantage. The whole object in hot-water work, in fact in water work of any kind, is to afford as full an opening as possible, and to change the direction of flow as little as possible, as change in direction means added friction. For steam, however, a slight change in direction makes no difference, but it is essential to obtain a good seating for the valves. In a low-pressure steam-heating plant, there will be less energy

expended in friction in the pipes themselves than in a hot-water apparatus, as in the latter case the medium is a fluid and in the former a gas.

CHAPTER VII

COMBINED STEAM AND HOT-WATER APPARATUS AND GENERAL CONCLUSIONS

In the arrangements described hitherto **the position of the boiler** has always been at the lowest point, but it is sometimes inconvenient to place it in that position, and excavation may be needed, which often entails difficulties with ground-water. In recent years several methods have been adopted which enable this difficulty to be surmounted, and many installations may now be found where the boiler is placed above some of the radiators. One of the systems is known as the "**Reck**" and was the invention of a Danish engineer, and another is Barker's "**Cable**" system; both these systems are worked by Messrs. G. N. Haden & Sons of Trowbridge, who are the sole licensees for the United Kingdom.

Other firms carry out similar arrangements, and we have examined an installation put into a London warehouse by **Messrs. Werner, Pfleiderer, & Perkins,** where the boiler was fixed upon the third floor, and the whole of the floors were heated, including the basement. Fig. 554A will give a general idea of this firm's method, arranged for the heating of a private house. A is a hot-water boiler, which has the usual outlet-pipe at the top and return at the bottom. Inside the firing chamber of the boiler is a pipe-coil B, in which steam is generated; the steam passes to the displacer C, and presses water therefrom through the non-return valve E into the bottom of the water-heater A. A similar quantity of water is thus also pressed from the top of the heater through the flow-pipe S, and around the circulating mains into the expansion-tank J; during this operation the non-return valve F is closed. When water has been displaced in the vessel C to the required level, steam enters the condenser D, and a vacuum is produced which closes the non-return valve E, opens the non-return valve F, and sucks water from the expansion-tank J through the return-pipe H and the condenser D, until the displacer C is again filled. This cycle of operations is repeated continuously and automatically.

The heater A may be placed in any desired position, not necessarily at the lowest part of the apparatus; in fact it may be placed at any level below the

expansion-tank, so that expensive excavation for the formation of a boiler-chamber below ground may be avoided.

It will be seen from the diagram that the pipes may be run up and down

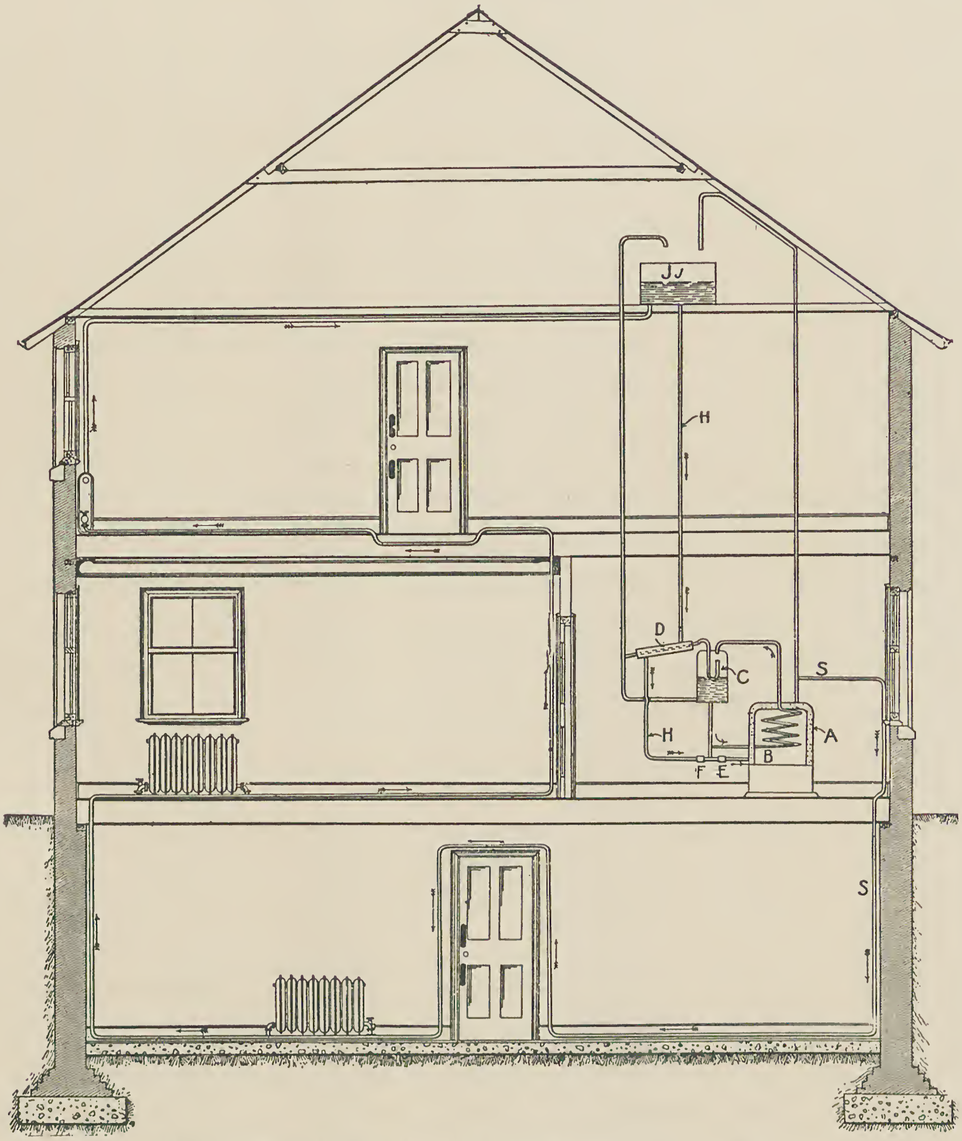


Fig. 554 A.—Messrs. Werner, Pfleiderer, & Perkins's System of Forced Circulation.

without regard to levels, and the pipes themselves may be of smaller diameter than in the ordinary gravity circulation system.

General Conclusions.—I consider **the system of open fires** of coal or wood to be by far the most healthy of all the systems which have now been described;

and, with due attention to the methods by which the consumption of fuel can be diminished, while greater efficiency in the use of the fuel is obtained, I do not see that it can well be improved upon for private houses in the British Isles. It is, however, desirable that a special supply of air should be brought to the fire from outside wherever possible.

Where it is desired to use **some auxiliary system,** then I consider that low-pressure hot-water is, taking it all round, the most suitable for general use, as being perfectly safe and requiring little attention. I do not consider systems of heating by heated air desirable, if they are to be used instead of fires, but as auxiliary means of providing general warmth, they may be of service; the chief objection in my mind to the use of heated air is, that it is necessary to breathe the heating medium, whereas the ideal to be aimed at is to heat the objects, the walls, and the persons in the rooms, while leaving the air comparatively cool for breathing. Systems of steam-heating and high-pressure hot-water heating have their uses as auxiliary means of heating, and are specially to be recommended where it is desirable to occupy as little space as possible with the pipes.

Close stoves and close fireplaces are, in my opinion, not to be recommended in preference to open fires, except upon the basis of lower financial cost of maintenance. The cold of the British winter is not usually so severe as to call for such means of heating, and although perfect smokelessness can be obtained by the use of some of these apparatus, yet the smoke can so far be diminished by the use of suitable open grates that they cease to be very objectionable in this respect.

Gas-fires are not, in the author's opinion, desirable, as there is usually a smell produced by them; if the register is not very carefully adjusted, either most of the heat disappears up the chimney, or, on the other hand, invisible products of combustion, in the form of carbonic acid gas, &c., are discharged into the apartment.

In closing, I would say again that it is desirable to warm the whole of the house and not a mere part of it, and to prevent draughts by arranging for special inlets and special outlets of the air, and this can be done perfectly in the case of new buildings, although probably with only partial success in the case of buildings already completed.

Section X.

WARMING AND COOKING BY ELECTRICITY

BY

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SECTION X.—WARMING AND COOKING BY ELECTRICITY.

Before entering upon a discussion of the merits and demerits of the utilization of electricity as a means of producing heat, either for cooking or warming, it would be well to consider the causes which have led to its adoption. Let us then, for a moment, consider **the means usually employed for cooking** in the kitchen of an ordinary home, *i.e.* the use of coal in an open range. The efficiency of such a method in the case (say) of roasting before the fire, is usually considered to be as low as from 10 to 15 per cent of the heat produced, and when we consider that the remaining percentage is either actually lost by going up the chimney, or is spent in making it generally uncomfortable for the cook, we feel that we have hardly got value for our fuel. Some slight improvement has been obtained by enclosing coal-fires in stoves. But even they, although not allowing the heat of the room to become excessive, still permit an enormous waste in the shape of hot air going up the chimney.

Another method of cooking very much in vogue consists in the use of gas-stoves. Careful experiments, however, have shown that, although obtaining a much higher efficiency than coal, with the additional advantage of no surrounding heat, about four-fifths of the total heat generated is, in the case of roasting, uselessly dispersed. In addition to this, food cooked over gas frequently has a disagreeable flavour, while the stove, even if it has ventilators attached, almost invariably gives off a quantity of noxious gases,—sometimes that known as "acetylene",—which are the direct cause of the headache, which usually comes on after entering a room in which a gas-stove has been burning.

A good cooking-apparatus should, in addition to being of moderate cost while actually in use, possess the following advantages:—1. No smell; 2. No external or radiant heat; 3. No generation of noxious vapours; 4. The quality of being able to be turned off or quenched, either partially or wholly, as cooking

proceeds or ends. These advantages, especially the last, may appear at first sight to savour somewhat of Arcadia, but, as I hope presently to point out, not only are they to be obtained, but are now actually within reach of the ordinary householder, by means of electricity.

A very popular impression seems to be that electricity, in its commercial form, can give no heat. So far, however, is this from being the case, that it is at present utilized to melt and weld metals which cannot be affected by other methods. This idea has no doubt arisen from the fact that buildings lighted by electricity are quite cool, when compared with those lit by other illuminants; the reason of this, however, is that electricity employed to give light yields such extraordinary brilliancy when compared with the actual size of the illuminating space, that such space, though in itself extremely hot, conveys hardly any additional heat to the surrounding atmosphere.

The theory upon which electrical heating is based is very simple. The reader is doubtless aware that all generators of electricity require an external circuit or path. In this path the work to be done invariably lies, whether it be in the shape of lighting, power-transmission, or any other means of absorbing electrical energy. The easier this path becomes, the greater is the rush of current down it; hence, as some metals are known to conduct the current with much greater ease than others, we say that they offer less resistance. To understand this aright, let us compare the flow of electricity along a wire with the flow of water in a pipe. We know that, with a certain head and pressure of water, a large pipe will allow an easy flow, while a small one will necessitate the forcing of the water through it with considerable difficulty. Electricity in a wire acts in a somewhat similar way; when the current is large and the conductor small, the latter becomes hot, owing to the resistance offered. Different metals, however, offer different degrees of resistance; thus, if we substitute an iron for a copper wire, the iron, although perhaps of exactly the same diameter as the copper, will get hot with the same current that the copper was able to conduct without heating. This fact—that resistance to a current produces heat—is the basis of cooking and warming by electricity.

The next point to be considered is, **how this heat can be produced without allowing any to escape.** We shall later see that the wires, by whose agency heat is to be produced, must be of high resistance; but few metals capable of offering this high resistance can withstand any great degree of heat, especially when exposed to the atmosphere. The commoner metals, otherwise most suitable, generally oxidize when subjected to an unusual degree of heat. The only method of preventing this oxidizing is so to enclose the resistance-wires that

the atmosphere cannot get at them; if such enclosure is perfect, the commoner metals may be used with impunity.

Resistance-wires used for heating-purposes are generally wound in spiral coils, as a great length of metal, and so of heating-surface, can thus be packed in small compass. Strange though it may seem, more difficulty has been experienced in obtaining an air-tight jacket for the coils than in perfecting the electrical part of the apparatus. The great difficulty was to find a composition which, while admitting no air, was capable of expanding, when heated, exactly in an equal ratio with the wires it enclosed. It will be seen that, given some such suitable compound, heat generated in the enclosed coils could, through contact with the compound, be much more readily conveyed to any pan or dish placed on it than if this were merely held over hot wires. And not only that, but such unprotected wires would be a constant source of danger from the possibility of a short circuit being formed. By a "short circuit" is meant a more direct path, and may be illustrated by a pan placed on two resistance-springs, through the total length of which the current would, in the ordinary course of things, be made to flow; the pan, being also of metal, would offer a much shorter circuit for the current than the many convolutions of the springs, and would, by thus allowing the electricity to bridge across, cause the springs, or that part of them short circuited, to become dead, and so lose the heat they possessed. The composition, therefore, must not only possess certain ratios of expansion, and be impervious to the passage of air, but it must also be made of insulating material; that is, of a material of the very worst conducting capacity, so that a short circuit cannot possibly occur through contact with the compound itself.

In the earlier experiments with heating-resistances, cement of different kinds was largely used, but owing to its breakable and porous nature, air very soon got to the wires, oxidation set in, and the apparatus became useless. The material in most frequent use now is a kind of enamel, which while possessing the necessary qualities mentioned above, is also a good conductor of heat, and is capable of adhering firmly not only to the wires imbedded in it, but also to the hot-plate to which the warmth is to be conducted. It will at once be seen that heat obtained by conduction is, for cooking, far superior to that due to radiation only.

The wires can be built in any shape to suit the requirements of the article to be heated, thus preventing the great loss of energy usually expended in uselessly heating the surrounding atmosphere; and not only this, for in the case of light goods, such as kettles, flat-irons, &c., the heating-springs are actually built into the article itself, thus not only doing away with the atmospheric

medium, but giving only one intervening plate to be heated, instead of at least the two used in the case last mentioned.

On coming into **a kitchen where an electric oven is in use** (see fig. 555), we are at once struck with the great difference between its surroundings and those pertaining to the old-fashioned range. Among the things which have disappeared are the smell of smoke, the risk of falling soot, and the high surrounding temperature due to keeping up a large fire for an hour or two

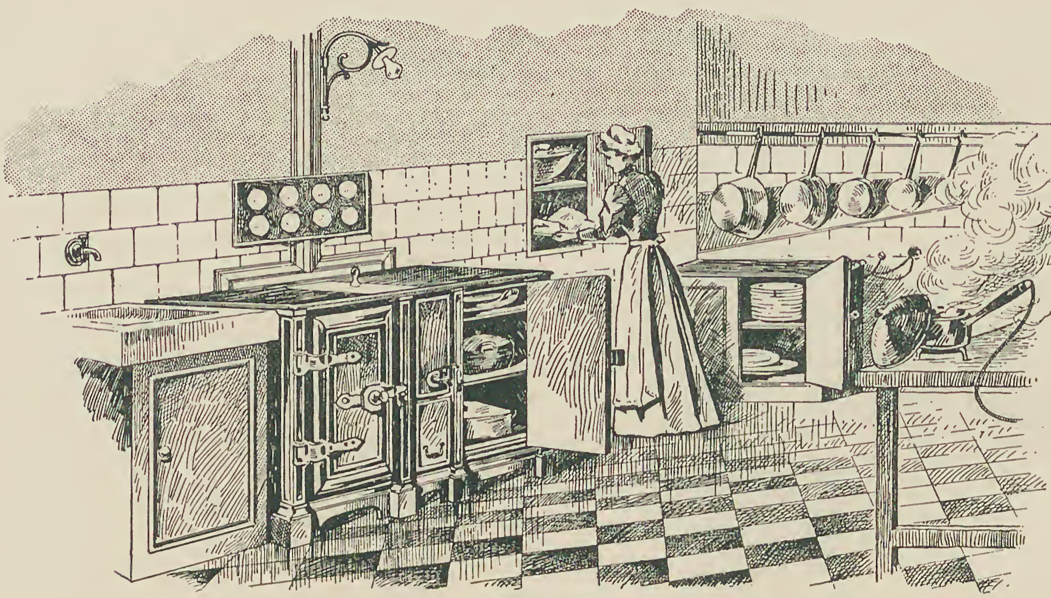

Fig. 555.—An Electric Kitchen.

before the oven is required in order to attain the necessary degree of heat; and there is no risk of finding that one side of the oven has been nearly red-hot, and has charred the eatables on one side, while the other is unbaked; or that the fire, not having been regulated with sufficient nicety, has either burnt the eatables or left them quite uncooked; for, by the peculiarities of construction above referred to, not only can we surround an electric oven with heating-surfaces on all sides, top or bottom, but, by merely turning the handle of a switch, we can regulate the current passing through these heating-surfaces, and consequently the degree of heat which any part of such an oven may attain, as shown in fig. 556. Thus, in an oven with six switches, all can be turned on to bake a certain article, and if this is not immediately required, all but one may be turned off, the remaining one being capable of keeping it warm. When we consider also that such an oven can attain its fullest heat in about 10 or 15 minutes after being first switched on, and can be turned out im-

mediately after use, we can at once see that the efficiency of electricity used in this direction is very high, and the cost consequently low; on the other hand, as all unnecessary heat is waste, the burning down of a coal-fire after use in cooking is dead loss. Nor is the evil of loss up the chimney only confined to the householder bearing it, for, as anyone living in a large town may see, it is these small contributions, and not those from mills and workshops, which make the atmosphere in all great centres what it is, ruinous alike to health and property.

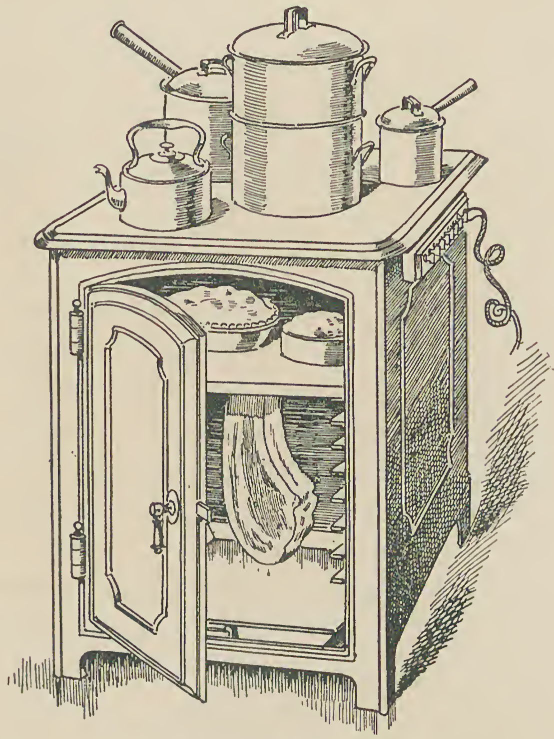

Fig. 556.—An Electric Oven.

Now as to cost. The energy will probably be obtained from an electricity supply station; for as electricity can be generated more cheaply on a large scale than on a small one, this is, with small consumers, the cheapest method of obtaining it. In Great Britain electrical energy is usually generated from steam power, and the price for current used for heating and motive purposes is about 2*d.* per unit.[1] For lighting, a higher rate is usually charged. In places where generating power can be obtained more economically, electrical energy is cheaper, for instance, in parts of America and the Continent, where electricity can be produced from large flows of water. We will assume that 2*d.* per unit is a fair standard on which to base our calculations, this being the actual amount now charged by many electricity supply stations for such purposes, though it is much higher than that at which an ordinary large private installation could supply it. We find that in an electric kettle 1 lb. of cold water can be boiled in approximately three minutes, with a current of 10 ampères at a pressure of 100 volts, which works out into units as follows:—

$$100 \text{ volts} \times 10 \text{ ampères} \times \tfrac{3}{60} \text{ hour} = 50 \text{ watt hours};$$

[1] By a "unit" is meant 1000 "watt hours", a watt being the standard of electrical energy, obtained by multiplying the pressure (or "voltage") of the circuit by the current (or "ampèrage") absorbed by any particular apparatus; in other words, when the electrical energy, multiplied by the time in hours, equals 1000, a unit of electricity has been expended. The definitions of the terms used in connection with electricity will be more fully given in the chapters on Lighting by Electricity, Section XII., Part I.

this, at $2d$ an unit, works out thus—

$$1000 : 50 :: 2 : \tfrac{1}{10} \text{ of a penny.}$$

An oven like that illustrated in fig. 556 will, with a pressure of 100 volts, take a current of approximately 25 ampères for about $\frac{1}{4}$ hour, by which time full cooking temperature of 325° to 400° Fahrenheit will be attained. After this first quarter of an hour a current of only 10 to 15 ampères will be sufficient to maintain this degree of heat.

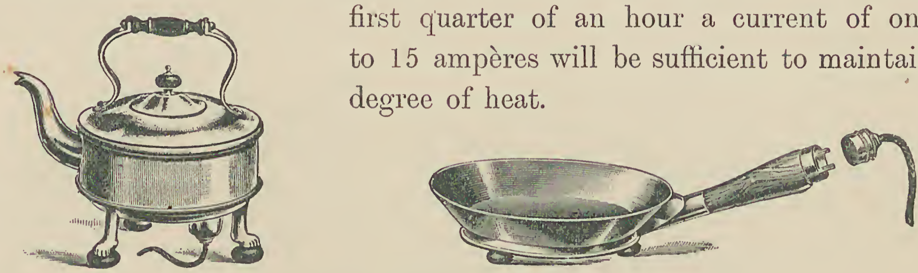

Fig. 557.—Electric Kettle and Fry-pan.

Care should be taken in the purchase of cooking or heating goods that they are built to suit **the pressure of the consumer's circuit,** for such pressures vary, and it will readily be seen that applying current at too great a pressure results in more current being forced through than it is capable of receiving without damage to it through overheating.

Small appliances, like kettles and other movable objects, usually get their connection by means of **two flexible silk-covered wires** in the form of a cord, at the end of which is a plug carrying two small metal terminals, which can be pushed into sockets fixed in different places on the wall for the purpose. This arrangement will be better understood by reference to the drawing of an electric fry-pan, shown in fig. 557. By means of the current supplied through these cords water can be boiled or kept boiling on the table where it is to be actually used. In the same way, flat-irons (fig. 558) can be coupled by means of the flexible cord through which the current passes, and as the electricity warms the iron while in actual use, there is no necessity for heating more than one iron, hence there is a considerable saving in time and labour.

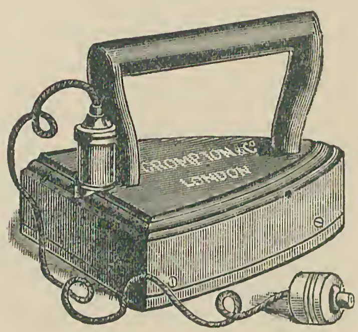

Fig. 558.—An Electric Flat-iron.

Other portable objects, such as curling-iron heaters, small radiators, cigar-lighters, foot-warmers, &c., can be heated in a similar way, in any position in which they are most useful. One of the most striking instances of efficiency in this direction is given by the electrical foot-warmer, which consumes a current

of one ampère only, which is little more than that taken by an ordinary incandescent light; with the unit at 2*d.*, such an arrangement in actual use would cost only $\frac{1}{5}d.$ per hour.

The efficiency of appliances of this description may be said almost to be perfect, since kettles and similar utensils have an efficiency of 80 to 90 per cent, and hot-plate warmers have an efficiency of from 90 to 95 per cent. By using a grill arrangement of hot plates similar to those just mentioned, a current of 5 ampéres at 100 volts will, in about 10 minutes, raise the apparatus to cooking-heat, while another 10 minutes, at a slightly reduced current, will be sufficient to cook two chops, which will thus be done at an expenditure of less than $\frac{1}{2}d.$, an amount which in many cases will hardly cover the cost of the chips used in lighting a coal-fire in an open range. Such an example, however, does not show the electric grill in its best light, as operations began with everything cold; if we continue to cook chops on the grill when the first two are finished, we shall find that the outlay will be less than $\frac{1}{4}d.$ per couple.

In the choice of cooking-appliances, it should be borne in mind that self-contained apparatus are the most efficient; that is to say, those articles in the bodies of which the heat is actually generated, as, for example, the oven shown in fig. 556.

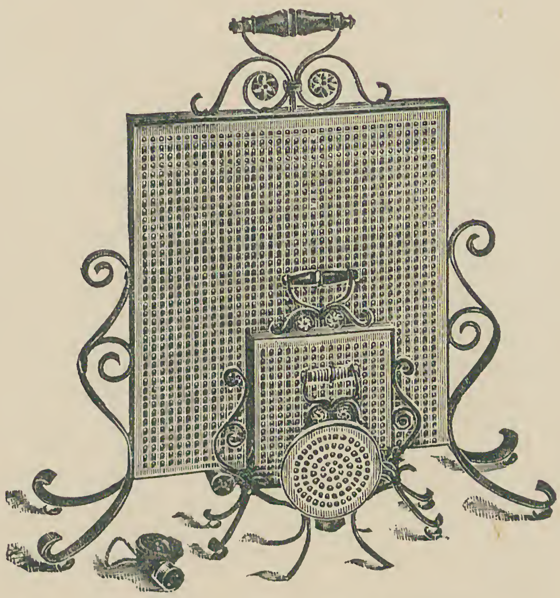

Fig. 559.—Electric Radiators in the form of Screens.

It will be manifest that **heating is almost identical with cooking,** both as regards appliances and cost. The only necessity is to convert the hot cooking-plate into something possessing a more artistic appearance, and then call it a radiator.

Electric radiators are made in many shapes and patterns, and quite ornamental in appearance. Their utility is manifest; not only do they do away with vitiated atmosphere from products of combustion, but they are under perfect control, and can be turned on or off as readily as any incandescent lamp.

Radiators for private houses, instead of being built as fixtures, are usually made portable in the shape of screens (fig. 559), or luminous heating lamps with reflectors (as shown in the side recesses in fig. 560), or boxlike receptacles

with heating coils (like the central part of fig. 560). In some radiators of the third type one or more ordinary incandescent lamps, with burnished metal reflectors or coloured glass screens, are fitted in order to give a bright appearance. All portable radiators possess the additional advantage, by means of their flexible connections, of being readily movable, and while, generally speaking, heating by such means is comparatively expensive, the advantage of being able to apply it quickly in any particular spot is, in many cases, invaluable.

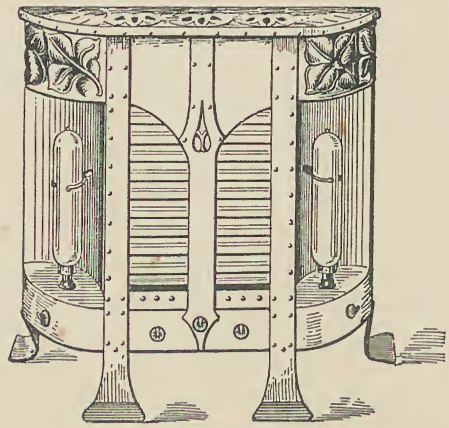

Fig. 560.—Luminous Electric Radiator.

The more general application of electricity to cooking and warming would, undoubtedly, purify the atmosphere and reduce labour, and thus not only tend to prolong life, but to make it easier and more pleasant.

Separate meters ought to be provided for recording the current consumed for heating and for lighting, and the wiring for the two purposes ought also to be quite distinct, as in nearly all districts supplied with electricity by public companies the rate charged for current used for heating is 50 per cent (or more) less than that charged for current used for lighting.